PROCEEDINGS

OF THE

Royal Society of Victoria.

VOL. XVII. (NEW SERIES).

PART I.

Edited under the Authority of the Council.

ISSUED SEPTEMBER, 1904.

(Containing Papers read before the Society during the months of May, June, July, 1904).

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AGENTS TO THE SOCIETY:
WILLIAMS & NORGATE, 14 HENRIETTA STREET, COVENT GARDEN, LONDON.
To whom all communications for transmission to the Royal Society of Victoria, from all parts of Europe, should be sent.

1904.

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THE AUTHORS OF THE SEVERAL PAPERS ARE SEVERALLY RESPONSIBLE FOR THE SOUNDNESS OF THE OPINIONS GIVEN AND FOR THE ACCURACY OF THE STATEMENTS MADE THEREIN.

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ERRATA.

Art. I.

p. 6, line 24, insert "closed circuit" before "type," and delete "treated in this section."

p. 7, line 22, read "E_1/D'" for "E_1/D_1."

p. 10, line 11, read "$\mathrm{Cos}(\delta+\phi)$" for "$\mathrm{Cos}(\theta+\phi)$."

p. 13, line 6, read "θ^2" for "θ_z."

p. 13, line 19, read "§ 14" for "§ 15."

p. 17, line 19, read "$\mathrm{Cos}\phi$" for "CosP."

p. 18, lines 2 and 3, read "P and $\mathrm{PCos}\phi$" for "P_2 and $P_2\mathrm{Cos}\phi$."

p. 28, line 4, read "θ" for "ϕ."

p. 29, line 7, insert "a" after "of."

p. 41, line 19, read "mutually" for "naturally."

p. 42, line 11, read "$b_2+\frac{b_1}{12}$" for "$b_1+\frac{b_1}{12}$."

p. 42, line 31, read "§ 47" for "§ 45."

p. 43, line 8, read "x'_2" for "x_2."

p. 47, line 29, read "$n_2{}^2C_2{}^2$" for "$n_2C_2^2$."

p. 48, line 14, read "f_2b_1" for "f_2b_2."

p. 48, line 29, read "$\frac{j^2-1}{i}b_1$" for "$\frac{j^2-1}{i}b_2$."

p. 54, line 4, read "x'_2" for "x'_1."

p. 61, line 8, read "§ 34" for "§ 33."

p. 62, line 11, insert reference number (V).

p. 65, line 8, after "in" insert "Section II. and in."

p. 70, line 30, read "$e^{-\iota\delta}$" for "$e^{\iota\delta}$."

p. 73, line 10, read "P_1" for "P."

p. 73, line 16, delete "that."

ART. I.—*The Alternate Current Transformer.*

By THOMAS R. LYLE, M.A.,

Professor of Natural Philosophy in the University of Melbourne.

(With Plates I.-V.).

[Read 9th June, 1904].

The following paper is divided into three Sections.

In Section I. the mathematical theory of the closed-circuit transformer for sinusoidal wave forms is developed, and reduced to a form suitable for practical application.

In Section II. is given an example of the application of the practical formulae obtained in Section I. to the design of transformers to operate different classes of load.

Section III. contains analytical investigations relating to magnetic leakage in transformers, to what are called the transformer numerics, and to the determination of the most efficient shapes of transformers of different types as well as a general solution of the transformer problem in which no assumptions with regard to leakage are made.

SECTION I.

1. It is well known that when an alternate magneto-motive force (M.M.F.) operates in a magnetic circuit (laminated), the M.M.F. per unit length (H, say) and the average flux density (B, say) can be expressed as follows :—

$$H = H_1[\mathrm{Sin}wt + h_3\mathrm{Sin}3(wt - y_3) + \&c.]$$
$$B = B_1[\mathrm{Sin}(wt - \delta) + b_3\mathrm{Sin}3(wt - \beta_3) + \&c.]$$

where the period is $2\pi/w$; and that the iron losses per cycle, per unit volume, due to hysteresis and eddy currents are equal in this case to

$$\frac{H_1B_1}{4}[\mathrm{Sin}\delta + 3h_3b_3\mathrm{Sin}3(\beta_3 - \gamma_3) + \&c.]$$

If $B_1 = \mu_0 H_1$ then μ_0 and δ will depend on B_1, w, and the wave form of H, as well as on the quality of the iron and the thickness of the laminae.

In some experiments on good transformer iron of thickness .04 cm. (q.p.), I have found by means of my wave tracer[1] that μ_0 and δ are given in terms of B_1 for periods .03 and .06 sec. by the curves shown in Fig. I., where the curves giving the corresponding iron losses are also shown.

In these experiments the wave forms of H were peaked, that is, the value of H at the crest was greater than the amplitude H_1 of its first harmonic. When the wave form of H is flat-topped, both μ_0 and δ are smaller for the same values of B_1 and w.

The values of B at the crests of the flux waves, corresponding to different values of B_1 the first harmonic, for the period .03 sec. are also given in Fig. 1, by the upper row of figures along the axis of x.

When the third and higher harmonics of H and B are neglected, the above equations take the simple forms,

$$\frac{\text{M.M.F.}}{\text{Length}} = \text{H}\operatorname{Sin} wt$$

$$\frac{\text{Flux}}{\text{Section}} = \text{B}\operatorname{Sin}(wt - \delta)$$

$$\text{B} = \mu\text{H}$$

$$\frac{\text{Iron losses per cycle}}{\text{Volume of iron}} = \frac{\text{HB}}{4}\operatorname{Sin}\delta$$

$$\frac{\text{Iron losses per second}}{\text{Volume of iron}} = \frac{w\text{B}^2}{8\pi\mu}\operatorname{Sin}\delta$$

which relations will be used in the following approximate theory of the transformer.

NOTATION.—The different periodic quantities considered will in the text be represented by letters such as $\overline{E_1}$, $\overline{C_1}$, $\overline{E_2}$, $\overline{C_2}$, with bars over them when the conception of both their amplitudes and phases is involved, while the amplitudes of these quantities will be represented by the same letters without the bar. Letters with the number 1 subscribed will refer to the primary, and with the number 2 subscribed to the secondary circuit.

The period of the alternations will be $2\pi/w$.

2. On the vector diagram, Fig. 2, let OR represent in amplitude and phase the resultant flux $\overline{F}$ looped on both the primary and secondary coils of a transformer.

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1 Phil. Mag., Nov., 1903.

This flux is produced by the ampere-turns

$\overline{n_1C_1 + n_2C_2}$ (a vector sum)

so that Amp. $\overline{F}$ or $F = \sigma \text{amp.} (\overline{n_1C_1 + n_2C_2})$

where $\sigma = 4\pi \times$ permeance of the magnetic circuit.

$$= 4\pi\mu \frac{\text{Section of iron}}{\text{Mean length of iron}}, \text{ for a closed circuit,}$$

and $\overline{F}$ is behind $\overline{n_1C_1 + n_2C_2}$ in phase by an angle δ. (See § 1).

[It will be shown that, throughout the range of operation of a transformer, when the primary volts and frequency are fixed, F is very nearly constant, so that δ and μ will be very nearly constant. On referring to Fig. 1, it will be seen that δ is fairly constant in any case in the neighbourhood of the flux densities generally used in transformers, and though, at the same densities μ is changing rapidly, we shall not, on account of the approximate constancy of F, introduce much error by assuming both δ and μ constant during the operation of the transformer.]

Hence from O draw OM, ahead of OR by the angle $\delta = \text{ROM}$, and in length equal to F/σ.

OM fully represents $\overline{n_1C_1 + n_2C_2}$.

In addition to the magnetic lines forming the main flux $\overline{F}$ and looped on both circuits of a transformer, there are others, the leakage lines, which are only partially looped on the circuits and whose action must be taken account of.

In Section III. of this paper it will be shown that, after the transformer is somewhat loaded, the effect of these leakage lines on its operation is the same as would be produced by two fluxes; one, the primary leakage flux, in phase with the primary current, and supposed to consist of lines that are looped on the primary circuit and miss the secondary, and the other, the secondary leakage flux, in phase with the secondary current and supposed to consist of lines that are looped on the secondary and that miss the primary circuit.

Let these two fluxes be specified by $x_1\sigma n_1\overline{C_1}$ and $x_2\sigma n_2\overline{C_2}$ where x_1 and x_2 are what we will call the *leakage coefficients* of the two circuits, and $\sigma = 4\pi \times$ permeance of the magnetic circuit as before.

3. The e.m.f. in the secondary coil being equal to

$$-n_2\frac{d\overline{F}}{dt}$$

is represented by the vector RS equal in length to $wn_2\mathrm{F}$ and behind $\overline{\mathrm{F}}$ in phase by a right angle.

For the present we will assume that the secondary current $\overline{\mathrm{C}_2}$ lags behind the internal secondary e.m.f. $\overline{\mathrm{E}'_2}$ or RS by an angle ϕ'. This angle will depend on the load and its power factor, as well as on the secondary magnetic leakage, and will subsequently be expressed as a function of these quantities.

From R draw RP making the angle $\mathrm{SRP}=\phi'$ and drop SP perpendicular to RP; then the vector RP fully represents $\overline{\mathrm{R}_2\mathrm{C}_2}$, where R_2 is the total resistance or its equivalent in the secondary circuit.

4. From M draw MN parallel to RP and equal to $n_2\mathrm{C}_2$, that is

$$\mathrm{MN}=n_2\mathrm{C}_2=n_2\frac{\mathrm{RP}}{\mathrm{R}_2}=n_2\frac{wn_2\mathrm{F}\mathrm{Cos}\phi'}{\mathrm{R}_2}=\theta'\mathrm{Cos}\,\phi'\frac{\mathrm{F}}{\sigma}$$

where $\theta'=\dfrac{wn_2{}^2\sigma}{\mathrm{R}_2}$,

then the vector NM represents $\overline{n_2\mathrm{C}_2}$, and as OM represents $\overline{n_1\mathrm{C}_1+n_2\mathrm{C}_2}$, we have $\overline{n_1\mathrm{C}_1}$ fully represented by the vector ON.

As the angle $\mathrm{OMN}=\frac{\pi}{2}+\delta+\phi'$ and $\mathrm{OM}=\mathrm{F}/\sigma$ we find that

$$\mathrm{ON}\ \text{or}\ n_1\mathrm{C}_1=\Delta'\frac{\mathrm{F}}{\sigma},\quad=\frac{\Delta'}{\theta'\mathrm{Cos}\phi'}n_2\mathrm{C}_2$$

where $\Delta'^2=1+2\theta'\mathrm{Cos}\phi'\mathrm{Sin}(\delta+\phi')+\theta'^2\mathrm{Cos}^2\phi'$.

If the angle MON be called χ, we find, by projecting the sides of the triangle OMN on OR and on a line perpendicular to OR, the relations

$$\Delta'\mathrm{Cos}(\chi+\delta)=\mathrm{Cos}\delta+\theta'\mathrm{Cos}\phi'\mathrm{Sin}\phi'$$
$$\Delta'\mathrm{Sin}(\chi+\delta)=\mathrm{Sin}\delta+\theta'\mathrm{Cos}^2\phi'$$

which will be useful.

5. From O along ON cut off a length OB that will represent $\overline{r_1\mathrm{C}_1}$, where r_1 is the resistance of the primary coil; OB will represent therefore the effective e.m.f. that produces current in the primary coil, and will be the vector sum of (*a*) the impressed e.m.f. $\overline{\mathrm{E}_1}$, (*b*) the e.m.f.

$$-n_1\frac{d\overline{\mathrm{F}}}{dt}$$

due to variation of the main flux $\overline{\mathrm{F}}$, and (*c*) the e.m.f.

$$-n_1\frac{d}{dt}(x_1\sigma n_1\overline{C_1})$$

due to variation of the primary leakage flux.

Hence from B draw BC perpendicular to ON and equal to

$wx_1n_1^2\sigma C_1=x_1\tau_1r_1C_1$ say,

where $\tau_1=\dfrac{wn_1^2\sigma}{r_1}$

CB will fully represent (*c*).

From C draw CE perpendicular to OR and equal to wn_1F, EC will fully represent (*b*).

Join OE. OE will fully represent E_1, the e.m.f. impressed on the primary of the transformer.

6. At this place attention may be drawn to the importance that will be attached in what follows to the quantities τ_1, τ_2, and θ'.

As τ_1 which we will call the *numeric of the primary circuit of the transformer* or, shortly, the *primary numeric*, is equal to

$$w\frac{n_1^2\sigma}{r_1}$$

and $\dfrac{n_1^2}{r_1}=\dfrac{n_1^2}{\rho n_1\dfrac{l_1}{a_1}}=\dfrac{n_1a_1}{\rho l_1}$

where a_1 = sectional area of primary wire

l_1 = mean length of primary turns

ρ = specific resistance of copper

also $\sigma=4\pi$. permeance of magnetic circuit. We see that τ_1 *is equal to* $4\pi w$ *into the conductance of the primary wires, considered as one turn or belt, into the permeance of the magnetic circuit.*

τ_2 is a similar constant for the secondary circuit, and will generally be nearly equal to τ_1; we will call it the *secondary numeric.* In what follows the ratio of τ_1 to τ_2 will where necessary be denoted by f so that

$$f=\frac{\tau_1}{\tau_2}=\frac{\dfrac{n_1^2}{r_1}}{\dfrac{n_2^2}{r_2}}=\frac{\dfrac{n_1a_1}{l_1}}{\dfrac{n_2a_2}{l_2}}$$

On the other hand θ' is a variable, varying with the load on the transformer, and for a given load-power-factor approximately as the load.

R_2 being the total resistance or its equivalent in the secondary circuit

$$\theta' = \frac{wn_2^2\sigma}{R_2} = \frac{r_2\tau_2}{R_2}$$

It is worth noting that τ_1, τ_2, and θ' are of zero dimensions.

7. Returning to the diagram Fig. 2, if we call the angle EOB α, so that Cosα is the power factor of the transformer, we find by projecting the figure OECB on ON and on a line perpendicular to ON, that

$$E_1\text{Cos}\alpha = r_1C_1 + wn_1F\text{Sin}(\delta+\chi) = r_1C_1[1 + \frac{\tau_1}{\Delta'}\text{Sin}(\delta+\chi)]$$

$$= r_1C_1[1 + \frac{\tau_1}{\Delta'^2}(\text{Sin}\delta + \theta'\text{Cos}^2\phi')]$$

making use of the relations in §§ 4 and 5.

$$E_1\text{Sin}\alpha = x_1\tau_1 r_1C_1 + wn_1F\text{Cos}(\delta+\chi) = r_1C_1[x_1\tau_1 + \frac{\tau_1}{\Delta'}\text{Cos}(\delta+\chi)]$$

$$= r_1C_1[x_1\tau_1 + \frac{\tau_1}{\Delta'^2}[\text{Cos}\delta + \theta'\text{Cos}\phi'\text{Sin}\phi')]$$

whence, squaring and adding

$$E_1^2 = r_1^2C_1^2\left\{1 + x_1^2\tau_1^2 + \frac{\tau_1^2}{\Delta'^2} + \frac{2\tau_1}{\Delta'}[\text{Sin}(\delta+\chi) + x_1\tau_1\text{Cos}(\delta+\chi)]\right\}$$

or $C_1 = \frac{E_1}{r_1\tau_1}\frac{\Delta'}{D'}$

where $D'^2 = 1 + 2x_1\text{Cos}\delta + 2\frac{\text{Sin}\delta}{\tau_1} + 2\theta'\text{Cos}\phi'(x_1\text{Sin}\phi' + \frac{\text{Cos}\phi'}{\tau_1}) + \Delta'^2\left(x_1^2 + \frac{1}{\tau_1^2}\right)$

Dividing $E_1\text{Sin}\alpha$ by $E_1\text{Cos}\alpha$

$$\tan\alpha = \frac{\text{Cos}\delta + \theta'\text{Cos}\phi'\text{Sin}\phi' + x_1\Delta'^2}{\text{Sin}\delta + \theta'\text{Cos}^2\phi' + \frac{1}{\tau_1}\Delta'^2}$$

The above relations enable us to determine practically τ_1 and δ for any closed-circuit transformer. For on open secondary $\theta' = 0$.

$$\Delta' = 1. \quad D' = 1 + x_1\text{Cos}\delta + \frac{\text{Sin}\delta}{\tau_1} = 1 \text{ (q.p.)},$$

as it will be shown later on that x_1 is always a small fraction and τ_1 a large number for a transformer of the type treated in this section. Hence if C_0 be the primary current on open secondary

$$\tau_1 = \frac{E_1}{r_1 C_0\left(1 + x_1 \operatorname{Cos}\delta + \frac{\operatorname{Sin}\delta}{\tau_1}\right)} = \frac{E_1}{r_1 C_0}$$

[The same is obvious otherwise, for

$$r_1\tau_1 = wn_1^2\sigma = wL_1$$

where L_1 is the inductance of the primary on open secondary].

Also on open secondary as $\theta' = 0$, &c.

$$\tan a = \frac{\operatorname{Cos}\delta + x_1}{\operatorname{Sin}\delta + \frac{1}{\tau_1}} = \operatorname{Cot}\delta \text{ (q.p.)}$$

or $\operatorname{Cos}a = \operatorname{Sin}\delta$

that is, *the power factor of a closed circuit transformer on open secondary is equal to the sine of the angle of magnetic retardation of its iron for the period aud flux density used.*

8. In the diagram Fig. 2, we see that $\overline{C}_2$ is behind $\overline{C}_1$ in phase by an angle $\pi - \beta$ where $\beta = ONM$.

Projecting ON on NM and on a line perpendicular to NM, we find that

$$\Delta' \operatorname{Cos}\beta = \operatorname{Sin}(\delta + \phi') + \theta' \operatorname{Cos}\phi'$$

$$\Delta' \operatorname{Sin}\beta = \operatorname{Cos}(\delta + \phi').$$

Also if $\overline{C}_2$ be behind E_1 in phase by an angle $\pi + \lambda$ we see that $\lambda = a - \beta$.

9. The amplitudes of the different quantities can now be written down in terms of E_1 as follows :—

$$C_1 = \frac{E_1}{r_1\tau_1}\frac{\Delta'}{D'},$$

$$wn_1F = \frac{E_1}{D_1}$$

$$\text{Amp } \overline{(n_1C_1 + n_2C_2)} = \frac{F}{\sigma} = \frac{n_1C_1}{\Delta'} = \frac{n_2C_2}{\theta' \operatorname{Cos}\phi'} = \frac{E_1}{r_1\tau_1}\frac{n_1}{D'}$$

and if E'_2 be the total e.m.f. generated in the secondary,

$$E'_2 = wn_2F = \frac{n_2}{n_1}\frac{E_1}{D'},$$

The total power P'_2 developed in the secondary

$$= \tfrac{1}{2}E'_2C_2 \operatorname{Cos}\phi' = \tfrac{1}{2}r_1C_1^2\frac{\theta'\tau_1\operatorname{Cos}^2\phi'}{\Delta'^2} = \frac{E_1^2}{2r_1\tau_1}\frac{\theta'\operatorname{Cos}^2\phi'}{D'^2}.$$

10. If $\overline{E}_2$ be the terminal e.m.f. of the secondary and $\operatorname{Cos}\phi$ the power factor of the load, the relations connecting these

quantites with $\overline{E'_2}$, $\text{Cos}\phi'$, etc., can now be obtained as follows:—

From SP Fig. 2 cut off ST so that

$$ST = wx_2n_2^2\sigma C_2 = x_2\theta' R_2C_2$$

then ST represents $-n_2\frac{d}{dt}(x_2\sigma n_2\overline{C_2})$

that is, the e.m.f. in the secondary due to variation of its leakage flux.

From RP cut off $RQ = r_2C_2$, then RQ represents the ohmic drop in the secondary.

Subtracting the vectors ST and RQ from RS (which represents the total e.m.f. in the secondary), we get QT, which fully represents $\overline{E_2}$, the terminal e.m.f., and the angle $PQT = \phi$ where $\text{Cos}\phi$ is the power factor of the load.

If R be the *external* resistance or its equivalent in the secondary circuit

so that $R = R_2 - r_2$, and if

$$\theta = \frac{wn_2^2\sigma}{R}$$

then as $\theta' = \dfrac{wn_2^2\sigma}{R_2}$ and $\tau_2 = \dfrac{wn_2^2\sigma}{r_2}$

we have $\dfrac{1}{\theta'} = \dfrac{1}{\theta} + \dfrac{1}{\tau_2}$. (I.)

Since $\dfrac{QP}{RP} = \dfrac{R_2 - r_2}{R_2} = \dfrac{R}{R_2} = \dfrac{\theta'}{\theta}$

$$E_2\theta\text{Cos}\phi = E_2'\theta'\text{Cos}\phi'$$

or $E_2 = \dfrac{\theta'\text{Cos}\phi'}{\theta\text{Cos}\phi}\ \dfrac{n_2}{n_1}\ \dfrac{E_1}{D'}$ (see § 9).

Again since $PS = PT + TS$

$$R_2C_2\tan\phi' = RC_2\tan\phi + wn_2^2\sigma x_2C_2$$

$$\frac{\tan\phi'}{\theta'} = \frac{\tan\phi}{\theta} + x_2 \ . \qquad \text{(II.)}$$

By means of the relations I. and II. we can now transform the formulæ already obtained in θ' and ϕ' to others in θ and ϕ.

11. Before doing so, however, it will be well to direct attention to the possible values of τ_1, τ_2, θ, θ', x_1, x_2, and $\text{Sin}\delta$, as when these are considered the formulæ admit of considerable simplification through dropping terms of negligible value.

The constants τ_1 and τ_2 for a transformer of 1 K.W. capacity at 50 periods would in no case be less than 1200, and it will be shown in Section III. (§ 55), that for similar transformers they are proportional to the square root of the output, and to the square root of the frequency.

The greatest practical value of θ or θ' for any transformer will not be much above

$\sqrt{\frac{\tau \text{Sin}\delta}{2}}$ where τ is the mean of τ_1 and τ_2

unless in case of excessive overload.

The leakage coefficients x_1 and x_2 should each be less than .002; and in transformers whose coils are wound in sections and interleaved they become very much smaller.

δ, the angle of magnetic retardation, will lie between 40° and 55°, its value depending on the quality of the iron, thickness of laminæ, flux density and frequency; hence Sinδ will have a value between .65 and .8.

[The formulæ given in this paper are only roughly approximate when applied to open-circuit transformers, as will be explained further on.

For them the τ constants are roughly .05 – .04 times the constants of closed-circuit transformers of the same capacity while Sinδ=.15—.08.]

12. Since $\frac{1}{\theta'^2 \text{Cos}^2\phi'} = \frac{1}{\theta'^2} + \frac{\tan^2\phi'}{\theta'^2}$

we find on substituting for $\frac{1}{\theta'}$ and $\frac{\tan\phi'}{\theta'}$ from equations I. and II. of § 10 that

$$\frac{\theta \text{Cos}\phi}{\theta' \text{Cos}\phi'} = \text{M}$$

where $\quad \text{M}^2 = 1 + 2\left(x_2 \text{Sin}\phi + \frac{\text{Cos}\phi}{\tau_2}\right) \theta \text{Cos}\phi + \left(x_2^2 + \frac{1}{\tau_2^2}\right) \theta^2 \text{Cos}^2\phi$

From § 4 we have

$$\frac{\Delta'^2}{\theta'^2 \text{Cos}^2\phi'} = 1 + \frac{2\text{Sin}(\delta+\phi')}{\theta' \text{Cos}\phi'} + \frac{1}{\theta'^2 \text{Cos}^2\phi'}$$

$$= 1 + \frac{2\text{Sin}\delta}{\theta'} + 2\text{Cos}\delta \frac{\tan\phi'}{\theta'} + \frac{1}{\theta'^2} + \frac{\tan^2\phi'}{\theta'^2}$$

substituting as before we find that

$$\frac{\Delta'^2}{\theta'^2 \text{Cos}^2\phi'} = \frac{\Delta^2}{\theta^2 \text{Cos}^2\phi}$$

where $\Delta^2 = \theta^2\mathrm{Cos}^2\phi\left(1 + 2x_2\mathrm{Cos}\delta + 2\dfrac{\mathrm{Sin}\delta}{\tau_2}\right) +$

$$\theta\mathrm{Cos}\phi\mathrm{Sin}(\delta+\phi) + \mathrm{M}^2$$

in which, for all practical purposes, M^2 may be taken $=1$.

Similarly $\dfrac{\mathrm{D}'^2}{\theta'^2\mathrm{Cos}^2\phi'} = \dfrac{\mathrm{D}^2}{\theta^2\mathrm{Cos}^2\phi}$

where, after dropping insignificant terms,

$$\mathrm{D}^2 = 1 + 2x_1\mathrm{Cos}\delta + 2\frac{\mathrm{Sin}\delta}{\tau_1} + 2\theta\mathrm{Cos}\phi(\mathrm{X}\,\mathrm{Sin}\phi + \mathrm{T}\,\mathrm{Cos}\phi) + \theta^2\mathrm{Cos}^2\phi(\mathrm{X}^2 + \mathrm{T}^2)$$

in which $\mathrm{X} = x_1 + x_2$

$$\mathrm{T} = \frac{1}{\tau_1} + \frac{1}{\tau_2}.$$

We also find

$$\tan\alpha = \frac{\mathrm{Cos}\delta + \theta\mathrm{Cos}\phi\mathrm{Sin}\phi + \mathrm{X}\theta^2\mathrm{Cos}^2\phi}{\mathrm{Sin}\delta + \theta\mathrm{Cos}^2\phi + \mathrm{T}\theta^2\mathrm{Cos}^2\phi}$$

$$\tan\beta = \frac{\mathrm{Cos}(\theta+\phi)}{\mathrm{Sin}(\delta+\phi) + \theta\mathrm{Cos}\phi} \quad \text{(see § 8).}$$

$$\tan\lambda = \frac{\tan\phi + \theta\mathrm{X}}{1 + \theta\mathrm{T}}.$$

13. Transforming the equations in § 9 by means of the relations in § 12, we get

$$\mathrm{C}_1 = \frac{\mathrm{E}_1}{r_1\tau_1}\,\frac{\Delta}{\mathrm{D}}$$

$$wn_1\mathrm{F} = \frac{\mathrm{M}}{\mathrm{D}}\mathrm{E}_1$$

$$\frac{1}{\mathrm{M}}\,\frac{\mathrm{F}}{\sigma} = \frac{n_1\mathrm{C}_1}{\Delta} = \frac{n_2\mathrm{C}_2}{\theta\mathrm{Cos}\phi} = \frac{\mathrm{E}_1}{r_1\tau_1}\,\frac{n_1}{\mathrm{D}}$$

$$\mathrm{E}_2 = \frac{n_2}{n_1}\,\frac{\mathrm{E}_1}{\mathrm{D}} \quad \text{(see § 10).}$$

$$\mathrm{P}'_2 = \tfrac{1}{2}\frac{\mathrm{E}_1^2}{r_1\tau_1}\,\frac{\theta\mathrm{Cos}^2\phi}{\mathrm{D}^2}\left(1 + \frac{\theta}{\tau_2}\right)$$

and if P_2 be the output of the transformer

$$\mathrm{P}_2 = \tfrac{1}{2}\mathrm{E}_2\mathrm{C}_2\mathrm{Cos}\phi = \tfrac{1}{2}\frac{\mathrm{E}_1^2}{r_1\tau_1}\,\frac{\theta\mathrm{Cos}^2\phi}{\mathrm{D}^2}$$

also if H_1 and H_2 be the copper l
respectively,

$$\mathrm{H}_1 = \tfrac{1}{2}r_1\mathrm{C}_1^2 = \tfrac{1}{2}\,\frac{\mathrm{E}_1^2}{r_1\tau_1^2}\,\frac{\Delta^2}{\mathrm{D}^2}$$

$$H_2 = \tfrac{1}{2} r_2 C_2^2 = P_2' - P_2 = \tfrac{1}{2} \frac{E_1^2}{r_1 \tau_1 \tau_2} \; \frac{\theta^2 \operatorname{Cos}^2\phi}{D^2}$$

where M, Δ, and D have the values given in the last paragraph.

14. When we multiply both sides of the first equation in § 7 by $\tfrac{1}{2}C_1$, we get

$$\tfrac{1}{2} E_1 C_1 \operatorname{Cos} a = \tfrac{1}{2} r_1 C_1^2 \left\{ 1 + \frac{\tau_1}{\Delta'^2} (\operatorname{Sin}\delta + \theta' \operatorname{Cos}^2\phi') \right\}$$

which expresses the power P_1 supplied to the transformer as the sum of three terms, of which the first

$$\tfrac{1}{2} r_1 C_1^2 = H_1$$

is equal to the copper loss in the primary coil; the second term

$$\tfrac{1}{2} r_1 C_1^2 \frac{\tau_1 \operatorname{Sin}\delta}{\Delta'^2} = H_3 \text{ say,}$$

is equal to the total iron loss in the transformer; and the third term

$$\tfrac{1}{2} r_1 C_1^2 \frac{\theta' \tau_1 \operatorname{Cos}^2\phi'}{\Delta'^2} = P_2' \text{ say.}$$

is equal to the power passed down to, and developed in the secondary coil:—

For, neglecting rC^2 losses, the energy entering the transformer on the primary side in any element of time dt is $n_1 \overline{C_1} \frac{d\overline{F}}{dt} dt$, and the energy leaving the transformer on the secondary side in the same element of time dt is $-n_2 \overline{C_2} \frac{d\overline{F}}{dt} dt$, hence in the time dt the transformer absorbs energy to the amount

$$\overline{n_1 C_1 + n_2 C_2} \frac{d\overline{F}}{dt} dt,$$

of which a part dM goes to increase the magnetic energy of the iron, while the remainder dW is dissipated as heat by hysteresis and eddy currents.

But amp. $\overline{n_1 C_1 + n_2 C_2} = F/\sigma$ so that we may write $\overline{n_1 C_1 + n_2 C_2} = \frac{F}{\sigma} \operatorname{Sin} [illegible]$ in which case [illegible] $\operatorname{FSin}(wt - \delta)$ where δ is the angle of [illegible]

[illegible] $\operatorname{Cos}(wt - \delta) dt$.

[illegible] M returns to its original

$$W=\tfrac{1}{2}wT\frac{F^2}{\sigma}\text{Sin}\delta$$

hence (as the core loss per second $H_8=W/T$)

$$H_8=\tfrac{1}{2}w\frac{F^2}{\sigma}\text{Sin}\delta$$

$$=\tfrac{1}{2}r_1C_1{}^2\frac{\tau_1\text{Sin}\delta}{\Delta'^2}\ \text{(see § 9).}$$

In § 9, P'_2 the total power passed down to and developed in the secondary was shown to be equal to

$$\tfrac{1}{2}r_1C_1{}^2\frac{\theta'\tau_1\text{Cos}^2\phi'}{\Delta'^2}$$

so that the different portions H_1, H_8 and P'_2 into which P_1 is divided are accounted for, and in § 13 are given the secondary copper loss H_2 and the output P_2 into which P'_2 is subsequently divided.

Transforming the above expression for H_8 to one in terms of θ and ϕ by § 13 we find

$$H_8=\tfrac{1}{2}\frac{E_1{}^2}{r_1\tau_1}\frac{M^2}{D^2}\text{Sin}\delta$$

and collecting the other power expressions

$$H_1=\tfrac{1}{2}\frac{E_1}{r_1\tau_1{}^2}\frac{\Delta^2}{D^2}$$

$$H_2=\tfrac{1}{2}\frac{E_1{}^2}{r_1\tau_1\tau_2}\frac{\theta^2\text{Cos}^2\phi}{D^2}$$

$$P'_2=\tfrac{1}{2}\frac{E_1{}^2}{r_1\tau_1}\frac{\theta\text{Cos}^2\phi}{D^2}$$

$$P_1=P_2+H_1+H_2+H_8.$$

It is worth noting that, as $M/D=1$ to the first order, the iron loss H_8, and the flux F will, to the same order, be constant throughout the range of operation of a transformer.

15. The efficiency η, of the transformer being

$$=\frac{P_2}{P_1}=\frac{P_2}{P_2+H_1+H_2+H_3}$$

we have $\eta=\dfrac{\theta\text{Cos}^2\phi}{\theta\,\text{Cos}^2\phi+\dfrac{\Delta^2}{\tau_1}+\dfrac{\theta^2\text{Cos}^2\phi}{\tau_2}+M^2\text{Sin}\delta}$

$$=\frac{\theta\,\text{Cos}^2\phi}{\Omega},\ \text{where}\ \Omega=\text{Sin}\,\delta+\frac{1}{\tau_1}+\theta\,\text{Cos}\,\phi\Big\{\,\text{Cos}\,\phi\,+$$

$$\frac{2\operatorname{Sin}(\delta+\phi)}{\tau_1}+2\left(x_2\operatorname{Sin}\phi+\frac{\operatorname{Cos}\phi}{\tau_2}\right)\operatorname{Sin}\delta\Big\} + \theta^2\operatorname{Cos}^2\phi$$

$$\times\left\{\frac{1}{\tau_1}+\frac{1}{\tau_2}+\frac{2}{\tau_1}\left(x_2\operatorname{Cos}\delta+\frac{\operatorname{Sin}\delta}{\tau_2}\right)+\left(x_2^{\,2}+\frac{1}{\tau_2^{\,2}}\right)\operatorname{Sin}\delta\right\}$$

To find the value of θ, for which η is a maximum when ϕ is constant, we note that η is of the form

$$\frac{\theta}{a+b\theta+c\theta^2}$$

which is a maximum when $\theta_2=a/c=\theta_0^{\,2}$ (say), and its maximum value is

$$\frac{1}{b+2a/\theta_0}.$$

Hence the value of θ for maximum efficiency is given by

$$\theta^2\operatorname{Cos}^2\phi=\frac{\operatorname{Sin}\delta+\frac{1}{\tau_1}}{\frac{1}{\tau_1}+\frac{1}{\tau_2}+\frac{2}{\tau_1}\left(x_2\operatorname{Cos}\delta+\frac{\operatorname{Sin}\delta}{\tau_2}\right)+\left(x_2^{\,2}+\frac{1}{\tau_2^{\,2}}\right)\operatorname{Sin}\delta}$$

which for all practical purposes may be reduced to

$$\theta^2\operatorname{Cos}^2\phi=\frac{\operatorname{Sin}\delta}{\frac{1}{\tau_1}+\frac{1}{\tau_2}}$$

and the maximum efficiency is given to a sufficient approximation by

$$\eta(\max)=\frac{1}{1+\frac{2}{\operatorname{Cos}\phi}\sqrt{\left\{\frac{1}{\tau_1}+\frac{1}{\tau_2}\right\}\operatorname{Sin}\delta}+2x_2\tan\phi\operatorname{Sin}\delta}$$

Note.—It is obvious that all the formulae we have obtained will apply to non-inductive loads when we make $\phi=0$, and to loads having capacity when we make ϕ negative.

16. From §15 we find that the ratio of the copper losses H_1+H_2 to the iron loss H_3 is

$$=\frac{\frac{\triangle^2}{\tau_1}+\frac{\theta^2\operatorname{Cos}^2\phi}{\tau_2}}{M^2\operatorname{Sin}\delta}$$

Putting in this expression for $\triangle$ and M their values given in § 12 and then substituting for θ its value at maximum efficiency, we find that this ratio is

$$=1-\mathrm{Sin}\,\phi\left(x_2\mathrm{Sin}\delta-\frac{\mathrm{Cos}\delta}{\tau}\right)\sqrt{\frac{2\tau}{\mathrm{Sin}\delta}}+\text{ terms of lower orders,}$$

where in the second term we take $\tau_1=\tau_2=\tau$.

Hence at maximum efficiency, when the load is non-inductive ($\phi=0$) the copper and the iron losses of a closed-circuit transformer are very approximately equal, and differ by a small amount given by the above formula when the load is inductive.

17. To determine the value of θ (θ_z say) for which the copper losses are z times the iron loss; we have (see § 14)

$$\frac{\Delta^2}{\tau_1}+\frac{\theta^2\mathrm{Cos}^2\phi}{\tau_2}=z\mathrm{M}^2\mathrm{Sin}\delta$$

from which, after substituting for Δ and M their values given in § 12, θ_z can in general be determined.

For practical purposes θ_z will be given to a high order of accuracy by

$$\theta_z\,\mathrm{Cos}\,\phi=\sqrt{\frac{z\,\mathrm{Sin}\,\delta}{\mathrm{T}}+\frac{z\,\mathrm{Sin}\,\delta}{\mathrm{T}}\left(x_2\mathrm{Sin}\,\phi+\frac{\mathrm{Cos}\,\phi}{\tau_2}\right)}-\frac{\mathrm{Sin}(\delta+\phi)}{2}$$

where $\mathrm{T}=\frac{1}{\tau_1}+\frac{1}{\tau_2}$

18. In § 13 it has been shown that the output

$$\mathrm{P}_2=\tfrac{1}{2}\frac{\mathrm{E}_1^2}{r_1\tau_1}\frac{\theta\mathrm{Cos}^2\phi}{1+2x_1\mathrm{Cos}\,\delta+\frac{2\mathrm{Sin}\delta}{\tau_1}+2\theta\mathrm{Cos}\phi\left\{\mathrm{X\,Sin}\phi+\mathrm{T\,Cos}\phi\right\}+\theta^2\mathrm{Cos}^2\phi(\mathrm{X}^2+\mathrm{T}^2)}$$

where $\mathrm{X}=x_1+x_2$ and $\mathrm{T}=\frac{1}{\tau_1}+\frac{1}{\tau_2}$

Let $$\mathrm{P}_0=\tfrac{1}{2}\frac{\mathrm{E}_1^2}{r_1\tau_1\left\{1+2x_1\mathrm{Cos}\delta+2\frac{\mathrm{Sin}\delta}{\tau_1}\right\}}$$

$$=\frac{\text{Iron loss on open secondary}}{\mathrm{Sin}\delta}\qquad\text{(see § 14)}$$

$$=\frac{\text{Power absorbed on open secondary}}{\text{Power factor of transformer on open secondary}}\quad\text{(q.p.)}$$

and take $y=\frac{\mathrm{P}_2}{\mathrm{P}_0\mathrm{Cos}\phi}$

so that y is proportional to the output;
also let

$$\mathrm{XSin}\phi+\mathrm{TCos}\phi=p$$
$$\mathrm{XCos}\phi-\mathrm{TSin}\phi=q$$

and the above equation in P_2 can be put into the form

$$y=\frac{\theta\text{Cos}\phi}{1+2p\theta\text{Cos}\phi+\theta^2\text{Cos}^2\phi(p^2+q^2)}$$

or

$$y=\theta\text{Cos}\phi[1-2p\theta\text{Cos}\phi+(3p^2-q^2)\theta^2\text{Cos}^2\phi]$$

Inverting this series we get

$$\theta\text{Cos}\phi=y[1+2py+(5p^2+q^2)y^2]$$
$$=y\text{D}_0^2$$

[where $\text{D}_0=1+py+\frac{1}{2}(4p^2+q^2)y^2$]

a very important relation, as it will enable us to *transform all our formulae from the independent variable θ to what is the practically important independent variable, namely, the output of the transformer.*

19. Thus if we let

$$\text{C}_0=\frac{\text{E}_1}{r_1\tau_1\left(1+x_1\text{Cos}\delta+\frac{\text{Sin}\delta}{\tau_1}\right)}$$

= Primary current on open secondary,

the formulæ in § 13 become

$$\text{C}_1=\text{C}_0\sqrt{y^2\text{D}_0^2\left(1+2x_2\text{Cos}\delta+2\frac{\text{Sin}\delta}{\tau_2}\right)+2y\text{Sin}(\delta+\phi)+\frac{1}{\text{D}_0^2}}$$

$$\text{C}_2=\frac{n_1}{n_2}\text{D}_0\text{C}_0y$$

$$\frac{\text{F}}{\sigma}=n_1\text{C}_0\sqrt{\frac{1}{\text{D}_0^2}+2y\left(x_2\text{Sin}\,\phi+\frac{\text{Cos}\,\phi}{\tau_2}\right)+y^2\left(x_2^2+\frac{1}{\tau_2^2}\right)}$$

$$\text{E}_2=\frac{n_2}{n_1}\frac{\text{E}_1}{\text{D}_0\left(1+x_1\text{Cos}\delta+\frac{\text{Sin}\delta}{\tau_1}\right)}$$

also

$$\text{Iron loss}=\text{P}_0\text{Sin}\delta\left\{\frac{1}{\text{D}_0^2}+2y\left(x_2\text{Sin}\phi+\frac{\text{Cos}\phi}{\tau_2}\right)+y^2\left(x_2^2+\frac{1}{\tau_2^2}\right)\right\}$$

$$\text{Copper losses}=\text{P}_0\left\{y^2\text{D}_0^2\left(\frac{1}{\tau_1}+\frac{1}{\tau_2}+2\frac{x_2}{\tau_1}\text{Cos}\delta+2\frac{\text{Sin}\delta}{\tau_1\tau_2}\right)+2y\frac{\text{Sin}(\delta+\phi)}{\tau_1}\right.$$
$$\left.+\frac{1}{\text{D}_0^2\tau_1}\right\}$$

$$\tan\alpha=\frac{\text{Cos}\delta+y\text{Sin}\,\phi+(\text{X}+2p\text{Sin}\,\phi)y^2}{\text{Sin}\delta+y\text{Cos}\,\phi+(\text{T}+2p\text{Cos}\,\phi)y^2}\ (\text{q.p.})$$

$$\text{Cot}\beta=\tan(\delta+\phi)+\frac{y}{\text{Cos}(\delta+\phi)}\ (\text{q.p.})$$

$$\tan\lambda = \frac{\text{Sin}\phi + Xy}{\text{Cos}\phi + Ty} \text{ (q.p.)}$$

where a and $\pi+\lambda$ are the angles that $\overline{C}_1$ and $\overline{C}_2$ are behind $\overline{E}_1$ in phase respectively, and $\pi-\beta$ is the angle $\overline{C}_2$ is behind $\overline{C}_1$.

If $\pi+\epsilon$ be the angle $\overline{E}_2$ is behind $\overline{E}_1$ in phase, then

$$\epsilon = \lambda - \phi$$

and $\tan\epsilon = \dfrac{qy}{1+py}$

a small quantity of the first order, so that $\overline{E}_2$ and $\overline{E}_1$ are always approximately in opposite phases.

Obviously all the above formulae will apply to non-inductive loads when ϕ is made zero in them.

20. The pressure drop at the secondary terminals from no load to any value of the load can now be expressed in terms of the load, its power factor, the transformer numerics and the leakage coefficients as follows :—

We have (see § 19)

$$E_2 = \frac{n_2}{n_1} \frac{E_1}{D_0\left(1 + x_1\text{Cos}\delta + \dfrac{\text{Sin}\delta}{\tau_1}\right)}$$

so that

$$\frac{E_2 \text{ (at load given by } y)}{E_2 \text{ (at no load)}} = \frac{1}{D_0}$$

$$= \frac{1}{1 + py + \frac{1}{2}(4p^2 + q^2)y^2}$$

$$= 1 - py - \tfrac{1}{2}(2p^2 + q^2)y^2$$

and the percentage drop for any load given by y

$$= 100y[p + \tfrac{1}{2}(2p^2 + q^2)y].$$

Remembering the values of p and q (§ 18) we see that the drop depends on the sum of the reciprocals of the transformer numerics (*i e.* on T) and on the sum of the leakage coefficients. We also see that for non-inductive loads the leakage effect on the drop is only a second-order term, while for inductive loads it is a first-order term, thus showing how important it is to have a small leakage in a transformer that has to operate inductive loads.

21. If the transformer were so designed that at full load it works with maximum efficiency, then the full load value of y or

$$\frac{P_2}{P_0\text{Cos}\phi}=\sqrt{\frac{\text{Sin}\delta}{T}}\left\{1-2p\sqrt{\frac{\text{Sin}\delta}{T}}\right\}$$ (see §§ 15, 18).

and the percentage drop from no load to full load in such a case is

$$=100\sqrt{\frac{\text{Sin}\delta}{T}}\left\{p-\left(p^2-\frac{q^2}{2}\right)\sqrt{\frac{\text{Sin}\delta}{T}}\right\}$$

which shows that the limit of possible excellence in regulation of a transformer, designed as above and perfectly wound, *i.e.*, having no magnetic leakage, is when the percentage drop from no load to full load is

$$100\sqrt{T\text{Sin}\delta}\ \text{Cos}\phi.$$

It has already been shown that the maximum efficiency of a transformer is

$$=1-\frac{2}{\text{Cos}\phi}\sqrt{T\text{Sin}\delta}\quad \text{(q.p.)}$$

so that as regards both efficiency and regulation $\frac{1}{T\text{Sin}\delta}$ may be taken as the measure of the excellence of a transformer when the magnetic leakage or nature of the winding is not considered.

In general, for a transformer with negligible leakage, the percentage drop from no load to a load P_2 being

$$100\frac{P_2}{P_0\text{Cos}\phi}\ T\text{Cos}P$$

as $P_0=\frac{1}{2}\frac{E_1^2}{r_1\tau_1}$ (q.p.)

the drop (p.c.) $=200\frac{r_1P_2}{E_1^2}\left(1+\frac{\tau_1}{\tau_2}\right)$

$$=400\frac{r_1}{E_1^2}P_2\quad \text{(q.p.)}$$

Reducing to practical units we find that the percentage drop in a transformer cannot be less than

$$200\times\text{Primary ohms}\times\frac{\text{Output in Watts}}{(\text{Primary virtual volts})^2}$$

In no practical case is the leakage negligible, but with interleaved winding $y^2(x_1+x_2)^2$ will be very small and $y^2\left\{\frac{1}{\tau_1}+\frac{1}{\tau_2}\right\}^2$ is very small in transformers of 20 K.W. or over, hence for such transformers the drop per cent. from no load to a load P_2

$$=\frac{100P_2}{P_0\text{Cos}\phi}\left\{(x_1+x_2)\,\text{Sin}\phi+\left(\frac{1}{\tau_1}+\frac{1}{\tau_2}\right)\text{Cos}\phi\right\}\ \text{(q.p.)}$$

If P_2 be the capacity of the transformer as usually rated on non-inductive load, then $P_2\text{Cos}\phi$ will be its capacity on an inductive load of power factor $\text{Cos}\phi$, as for this output we get approximately the same secondary current as before. Hence we see from the preceding formula that if $X=\text{T}\tan\frac{\psi}{2}$ the regulution for loads whose power factors are less than $\text{Cos}\psi$ is better than that for non-inductive loads.

If the load has capacity then ϕ is negative, and the capacity effect in reducing the drop or even producing a rise in voltage with load can easily be deduced from the general expression for the drop given in § 20.

22. When the percentage drop of a transformer for a non-inductive load P_2 is known, we can by means of the formula in § 20 calculate the sum of its leakage coefficients.

For a non-inductive load—

$$\text{Drop (p.c.)}=100y\left\{\text{T}+\left(\text{T}^2+\frac{X^2}{2}\right)y\right\}$$

where in this case $y=\frac{P_2}{P_0}$

As P_0 is the power absorbed on open secondary divided by the power factor of the transformer on open secondary it can be determined. It has been shown in § 7 how to practically determine τ_1, and τ_2 can be obtained from τ_1 as follows:—

$$\frac{\tau_1}{\tau_2}=\frac{\frac{n_1^2}{r_1}}{\frac{n_2^2}{r_2}}\ (\S\ 6).$$

r_1 and r_2 can be measured and

$$\frac{n_1}{n_2}=\frac{\text{Primary volts}}{\text{Secondary volts on open secondary}}\ (\S\ 19).$$

Hence substituting in the above equation the values of y, T, and the drop, X or x_1+x_2 can be found.

It is obvious that we can also by means of the general formula in § 20 determine both x_1+x_2 and $\frac{1}{\tau_1}+\frac{1}{\tau_2}$ for any transformer from observations of the voltage drop for loads with different power

factors. This would not be a satisfactory method for determining the transformer numerics, as their values so obtained would depend on the correct reading of small differences.

23. As an illustration of how closely this theory agrees with practice I will discuss the following manufacturer's specification of the performance of a 10 K.W. Westinghouse O.D. transformer.

Primary volts, 2100 :— Frequency, 60 periods per sec.:—
Output, 10 K.W.:— Iron loss, 138 watts :—
Copper loss at full load, 159 watts :—

Efficiency (per cent.)		Regulation (per cent.)		
Full load	97.1	Power factor	1.0	1.65
$\frac{3}{4}$ load	97.05	" "	.9	2.45
$\frac{1}{2}$ load	96.55	" "	.8	2.65
$\frac{1}{4}$ load	94.4	" "	.6	2.80

In the first place we will find whether any definite values of X and T will simultaneously satisfy the four equations in these two quantities obtained from the four observations of drop for different power factors.

If we substitute x for yX and t for yT in the general expression in § 20 for the drop per cent. (R say) we get

$$R = 100\left\{x\operatorname{Sin}\phi + t\operatorname{Cos}\phi + x^2\left(\operatorname{Sin}^2\phi + \frac{\operatorname{Cos}^2\phi}{2}\right) + xt\operatorname{Sin}\phi\operatorname{Cos}\phi + t^2\left(\operatorname{Cos}^2\phi + \frac{\operatorname{Sin}^2\phi}{2}\right)\right\}$$

By means of this equation x and t were determined from the first two observations of the regulation and found to be

$x = .0218$, $t = .016$.

Using these values and calculating R for the power factors .8 and .6, we found that when

$\operatorname{Cos}\phi = .8 \quad R = 2.66$

$\operatorname{Cos}\phi = .6 \quad R = 2.78$

which agree very closely with the observed values of R, namely 2.65 and 2.80.

As in each case the full load is $10\operatorname{Cos}\phi$ K.W. (see § 21) and in the above

$$y = \frac{\text{Full load}}{P_0\operatorname{Cos}\phi}$$

we have at full load

$$y=\frac{10000}{P_0}.10^7$$

but $x=yX=.0218$ and $t=yT=.016$

$$\therefore 10^7\frac{X}{P_0}=\frac{.0218}{10000} \text{ and } 10^7\frac{T}{P_0}=\frac{\cdot 016}{10000} \qquad \text{(I.)}$$

where P_0 has its usual signification (see § 18).

The iron loss is given as 138 watts, and we may consider it as constant without introducing any appreciable error, so that

$$P_0\text{Sin}\delta=138.10^7$$

hence from (I.)

$$\left.\begin{aligned} X\,\text{Sin}\delta&=\frac{.0218\times 138}{10,000}=.000301\\ T\text{Sin}\delta&=\frac{.016\times 138}{10,000}=.000221\end{aligned}\right\} \qquad \text{(II.)}$$

The maximum efficiency of the transformer when $\text{Cos}\phi=1$ being very approximately

$$=\frac{1}{1+2\sqrt{T\text{Sin}\delta}} \qquad \text{(see § 15)}$$

is $=.971$

which is the same as the observed value at full load.

The copper losses H_1+H_2 when $\phi=0$ being

$$=P_0\left\{y^2D_0^2\left(\frac{1}{\tau_1}+\frac{1}{\tau_2}\right)+2y\frac{\text{Sin}\delta}{\tau_1}\right\} \qquad \text{(see § 19)}$$

$$H_1+H_2=\frac{T}{P_0}P_2^2\left(D_0^2+\frac{P_0\text{Sin}\delta}{P_2}\right)$$

$$10^7(H_1+H_2)=\frac{.016}{10000}P_2^2\left(D_0^2+\frac{138.10^7}{P_2}\right)$$

where, when $\text{Cos}\phi=1$,

$$D_0^2=1+2\frac{T}{P_0}P_2+\tfrac{1}{2}\left(6\frac{T_2}{P_0^2}+\frac{X^2}{P_0^2}\right)P_2^2 \qquad \text{(see § 18)}$$

and substituting from (I.)

$$D_0^2=1+\frac{32}{10^7}\,\frac{P_2}{10^7}+\frac{1}{10^{11}}\left(\frac{P_2}{10^7}\right)^2$$

Let the load be 10000 z watts so that z is the fraction of full load then

$$P_2=10000z\ 10^7$$

and the copper losses in watts for any fraction z of the full load are

$$=\frac{H_1+H_2}{10^7}=160z^2\left(1+\frac{32}{10^8 z}+\frac{1}{10^3}z^2+\frac{138}{10^4 z}\right)$$

from which we deduce for the transformer in question that the copper losses are

= 167 watts at full-load
= 94 watts at $\frac{3}{4}$ load
= 42 watts at $\frac{1}{2}$ load
= 10 watts at $\frac{1}{4}$ load.

The iron loss being 138 watts we find that the efficiency at full load is 97.04 per cent.,

that at $\frac{3}{4}$ load is 97.02 „ „
„ „ $\frac{1}{2}$ load is 96.54 „ „
„ „ $\frac{1}{4}$ load is 94.40 „ „

which figures, when compared with those in the maker's specification given above, show a very remarkable agreement.

Thus we have been able to deduce with considerable accuracy from two observations of the regulation for different power factors, and the observed iron loss, the other details of the transformer given by the manufacturer.

If we assume $\delta=50°$ which would mean that the power factor on open secondary was equal to Sinδ or .766, and take $\tau_1=\tau_2$ then $\tau_1=6930$ for this 10 K.W. 60 period transformer; and $x_1+x_2=$ .0004.

24. As a second illustration of the agreement between the foregoing theory and practice I will consider the record of a test of a Westinghouse transformer, published in Fleming's "Alternate Current Transformer," vol. i., pp. 564, 569.

From the no-load readings of C_1, P_1, and E_2 we can determine as has been explained (§§ 7, 19, 22) τ_1, Sinδ, n_1/n_2 and τ_2, while the voltage drop for any load enables us to find x_1+x_2 when τ_1, τ_2 and Sinδ are known (§ 22).

These constants together with r_1, r_2 and the primary voltage enable us to calculate all the variable quantities connected with the transformer for any load. This has been done for the above transformer tested by Fleming, and the calculated values of C_1, C_2, P_1, η, and Cosα for each output in his test are given in Table I. in parallel columns with the values experimentally obtained by him for these quantities.

As the whole behaviour of the transformer is to be evolved from the no-load readings for C_1, P_1, and E_2, and the full load reading of E_2, it is necessary that these should be obtained with accuracy.

The figures for C_1 and P_1 given in the record of the test were probably obtained very near the zeros of the scales of the ammeter and wattmeter used, so instead of relying on single readings I obtained the no-load values of C_1 and P_1 by plotting a few of the readings for them near no-load against the output, and taking the values given by the points where the curves obtained intersect the no-load axis.

In this way I find that C_1 at no-load = .058 amp. and P_1 = 110 watts, which values give the same power factor, .79, as Fleming obtained.

It will be seen on inspection of the following table, that the agreement between the values I have calculated and those observed by Fleming is remarkably close. A very slight modification or correction of the primary wattmeter readings, which the recorded values of the power factor seem to suggest, would make the agreement almost perfect when allowance is made for the inevitable variations from mathematical accuracy of any series of observations.

TABLE I.

Comparison of the measured values of the variables obtained in a test by Fleming of a Westinghouse transformer with values theoretically calculated by the author from no-load values and voltage drop.

Power, 6500 watts. Frequency, 82.5 periods per second.

$r_1 = 5.95$ ohms; $r_2 = 0.0108$ ohms, at 96°F.

$$E_1 = 2400 \text{ volts}; \; E_2 = \begin{cases} 101 \text{ volts at no-load} \\ 98.6 \text{ volts at 6384 watts.} \end{cases}$$

$$\left\{ \begin{array}{l} \tau_1 = 6950, \; \tau_2 = 6780, \; \text{Sin}\delta = 0.79, \; \frac{n_1}{n_2} = 23.76, \\ x_1 + x_2 = 0.003. \end{array} \right\}$$

Output P_2.	Primary Current C_1.		Secondary Current C_2.		Iron Loss Calculated.	Primary Watts P_1.		Efficiency in Per Cent.		Power Factor $\cos\alpha$.	
	Obsvd. (Fleming)	Calcd.	Obsvd. (Fleming)	Calcd.		Obsvd. (Fleming)	Calcd.	Test (Fleming)	Calcd.	Test (Fleming)	Calcd.
0	0.050	0.058	0	0	110.0	95	110	0	0	0.79	.79
101	0.100	0.095	1.00	1.00	110.0	205	211	49.3	47.9	0.85	.899
200	0.140	0.134	1.98	1.98	110.0	306	310	65.4	64.5	0.91	.951
296	0.180	0.173	2.94	2.93	109.9	401	406	73.7	72.9	0.93	.978
390	0.218	0.212	3.87	3.86	109.9	493	500	79.1	78.0	0.94	.983
482	0.250	0.250	4.79	4.78	109.9	597	592	80.7	81.4	0.99	.987
806	0.382	0.383	8.00	7.99	109.8	920	917	87.6	87.9	1.00	.998
1019	0.472	0.472	10.15	10.11	109.7	1139	1131	89.5	90.1	1.00	.998
1311	0.580	0.595	13.07	13.02	109.6	1440	1425	91.1	91.0	1.03	.998
1802	0.800	0.801	18.00	17.92	109.5	1930	1919	93.4	93.9	1.00	.998
1992	0.880	0.881	19.90	19.82	109.4	2118	2110	94.1	94.4	1.00	.998
2193	0.960	0.966	21.93	21.83	109.3	2330	2313	94.1	94.8	1.01	.998
2474	1.080	1.085	24.74	24.65	109.2	2609	2597	94.8	95.2	1.01	.997
2966	1.285	1.293	29.66	29.61	109.0	3096	3094	95.8	95.9	1.00	.997
3713	1.610	1.612	37.20	37.17	108.8	3870	3852	96.0	96.4	1.00	.996
4179	1.810	1.819	42.00	42.10	108.6	4324	4344	96.7	96.6	0.99	.995
4633	2.002	2.006	46.65	46.55	108.3	4792	4789	96.9	96.7	1.00	.995
5000	2.160	2.166	50.40	50.33	108.1	5174	5163	96.7	96.8	1.00	.994
5164	2.240	2.237	52.16	52.01	108.0	5422	5331	95.3	96.9	1.01	.993
5499	2.383	2.382	55.60	55.47	107.8	5702	5674	96.1	96.9	1.00	.993
5700	2.478	2.471	57.68	57.57	107.7	5885	5880	96.9	96.9	0.99	.992
5867	2.550	2.544	59.32	59.31	107.6	6041	6051	97.3	96.9	0.99	.991
6053	2.633	2.625	61.32	61.24	107.5	6271	6242	96.7	97.0	0.99	.991
6142	2.672	2.664	62.16	62.16	107.4	6344	6333	96.8	97.0	0.99	.991
6218	2.700	2.698	63.00	62.96	107.4	6426	6411	96.8	97.0	0.99	.990
6317	2.750	2.741	64.00	64.00	107.3	6522	6513	96.9	97.0	0.99	.990
6384	2.775	2.771	64.74	64.70	107.3	6598	6582	96.9	97.0	1.00	.990

25. The method by which magnetic leakage has been dealt with in the preceding theory is not applicable to open circuit transformers. It will be seen in Section III. that this method depends on the fact that in closed circuit transformers the vector $\overline{n_1C_1+n_2C_2}$ which represents the magnetizing ampere turns is small compared with either $\overline{n_1C_1}$ or $\overline{n_2C_2}$, throughout the greater portion of the working range; or, differently stated, that C_1 and C_2 are practically in opposition in phase, and that $n_1C_1-n_2C_2$ is small relatively to either n_1C_1 or n_2C_2 from a small fraction of full load onwards, in closed-circuit transformers.

In open-circuit transformers, on account of the great reluctance of their magnetic circuits, the magnetizing ampere turns are necessarily high, and neither of the two conditions stated above are approximately fulfilled unless over a small range near full load.

If we neglect leakage, or be satisfied with the rough approximation to its effects that the present method affords for open-circuit transformers, then the theory given—as it is equally valid in other particulars for the two types—will apply with fair approximation to accuracy to the open-circuit type, especially in the neighbourhood of full load.

There will be considerable difference, however, in the values of the constants and other characteristics of transformers of equal capacity of the two types.

Let us assume that we have two transformers, one of each type, in which the cores, of the same iron, have the same cross section and volume. Let τ_1, τ_2, δ, σ, θ refer to the closed, and τ_1^0, τ_2^0, δ^0, σ^0, θ^0 refer to the open circuit one. Then if they are so wound that when working under similar conditions their resultant fluxes F and F^0 are equal,

(*a*) Since $\frac{F}{\sigma} = \text{amp.}(\overline{n_1C_1 + n_2C_2})$

(where $\sigma = 4\pi$ permeance of magnetic circuit) their *magnetizing ampere turns will be inversely proportional to the permeances of their magnetic circuits.*

(*b*) Their iron losses will be equal or

$$\tfrac{1}{2}w\frac{F^2}{\sigma}\text{Sin}\delta = \tfrac{1}{2}w\frac{F^{02}}{\sigma^0}\text{Sin}\delta^0 \text{ (see § 14)}$$

and as $F = F^0$

$$\frac{\text{Sin}\delta}{\sigma} = \frac{\text{Sin}\delta^0}{\sigma^0}$$

or *the sines of the angles of magnetic lag of the two transformers are proportional to the permeances of their magnetic circuits.*

Again if the two cores, carrying equal fluxes, have their secondary coils such that the outputs and secondary voltages are equal, the sections of their secondary wires and the numbers of their secondary turns will be equal, and hence the conductivities of their secondary copper belts will be equal, so that

$$\frac{\tau_2}{\sigma}=\frac{\tau_2^0}{\sigma^0}\text{ (see § 6)}$$

or *the secondary numerics are proportional to the permeances of the two magnetic circuits.*

If the closed-circuit transformer be of the core type, so that its windings are similarly arranged to those of the other, then approximately,

$$\frac{\tau_1}{\sigma}=\frac{\tau_1^0}{\sigma^0}\text{ and hence }T\mathrm{Sin}\delta=T^0\mathrm{Sin}\delta^0.$$

If the method of treating leakage was equally legitimate for the two types, we have also, approximately,

$$\frac{x_1}{x_1^0}=\frac{x_2}{x_2^0}=\frac{\sigma^0}{\sigma}\text{ (see § 34), provided the windings are similar.}$$

For a non-inductive load,

$$\theta=\frac{P_2}{P_0}=\frac{P_2\mathrm{Sin}\delta}{\text{Iron loss}}$$

to the first order for both, hence if θ and θ^0 refer to the same output, that is to the same fraction of full load in each

$$\frac{\theta}{\theta^0}=\frac{\mathrm{Sin}\delta}{\mathrm{Sin}\delta^0}=\frac{\sigma}{\sigma^0}\text{ approximately}$$

that is, *the values of the co-ordinate θ for the same output are proportional to the permeances of the magnetic circuits.*

26. In order to compare the rates of approach to opposition of C_1 and C_2 in transformers of the two types, let us consider the equation

$$\mathrm{Cot}\beta=\tan(\delta+\phi)+\frac{y}{\mathrm{Cos}(\delta+\phi)}\quad\text{(see § 19)}$$

which is correct to the first order for both, where $\pi-\beta$ is the angle C_2 is behind C_1 in phase.

For a non-inductive load

$$y=\frac{P_2}{P_0}=\frac{P_2\mathrm{Sin}\delta}{\text{Iron loss}}=\frac{P_2}{H_8}\mathrm{Sin}\delta$$

so that

$$\mathrm{Cot}\beta=\tan\delta\left(1+\frac{P_2}{H_8}\right)$$

for both types when $\phi=0$.

But δ for the closed circuit type will be 50° or over, and for the open circuit (hedgehog) type will be about 4°; and if we assume (which will be sufficiently accurate for our present purpose) that in transformers of equal capacity of the two types

the iron losses are equal, we find, taking the figures for the 10 K.W. transformer discussed in § 23, that β will be given by the equation

$$\text{Cot}\beta = \tan\delta\left(1 + z\frac{10,000}{138}\right)$$

where z is the fraction of full load and $\delta = 50°$ for the closed-circuit, and $= 4°$ for the open-circuit transformer.

The figures in the following table, calculated from the above formula, show the relative approach to opposition of C_1 and C_2 in 10 K.W. transformers of the two types.

Fractions of Full Load - - -	0	0.1	0.25	0.5	1.0
β for closed-circuit transformer -	40°	5°	2.5°	1.3°	0.7°
β for open-current transformer -	86°	60°	37°	21°	11°

In both cases the approach to opposition will be quicker for larger transformers, as in them the iron loss is a smaller fraction of the full load output.

For inductive loads having a constant power factor $\text{Cos}\phi$

$$\text{Cot}\beta = \tan(\delta + \phi) + \frac{P_2\text{Sin}\delta}{H_3\text{Cos}\phi\text{Cos}(\delta + \phi)}$$

so that at no-load $\beta = \frac{\pi}{2} - (\delta + \phi)$ or C_1 and C_2 at the beginning of the range are nearer to opposition for both types than when the load is non-inductive, and as $\text{Cos}\phi\text{Cos}(\delta + \phi)$ is less than unity, the successive increments to $\text{Cot}\beta$ for definite fractions of the load will be greater; hence for both types of transformers the approach to opposition of C_1 and C_2 will be more marked with inductive than with non-inductive loads.

Section II.

27. The theory developed in Section I. is easily applicable to the design of a closed-circuit transformer, when the full load, power factor of the load, periodicity, and e.m.f.'s are given.

In the first place we would select the form of the magnetic circuit, and after consideration of the probable cooling surface,

volume, and method of cooling to be adopted, decide on the permissible copper and iron losses per unit volume.

If K be the copper loss decided on, per second, per unit volume, at full load, then

$K = \frac{1}{2}\rho c^2$,

whence c, the amplitude of the full-load current density, is known, ρ being the specific resistance of copper at the expected working temperature.

When the iron loss per second, per unit volume, (I. say) is given, the corresponding retardation δ, permeability and flux density can be got from curves similar to those in Fig. I., that have been obtained from a sample of the iron to be used with (*q.p.*) sine wave magnetising currents whose period was the given one.

If γ be the flux density (=B the abscissae in Fig. I.), then we should have between these quantities the relation,

$\frac{w\gamma^2 \mathrm{Sin}\delta}{8\pi\mu} = \mathrm{I.}$ (see § 1).

Once the form of the magnetic circuit has been selected, its dimensions can be completely specified by two variables. The output at full load, P_2 say, can be expressed in terms of these two variables, for P'_2, the power passed down to the secondary and developed in it, is given by the equation,

$P'_2 = \frac{1}{2} w n_2 C_2 F \mathrm{Cos}\phi'$ (I.)

and F = iron section × permissible flux density (γ),

$n_2 C_2$ = total copper section × permissible current density at full load (c).

P'_2 can be obtained from P_2 the given output, and $\mathrm{Cos}\phi'$ from $\mathrm{Cos}\phi$, the given power factor of the load, by the equations,

$$P'_2 = \left\{1 + \frac{\theta_z}{\tau}\right\} P_2$$

$$\text{and } \tan\phi' = \tan\phi + \left\{x_2 - \frac{\tan\phi}{\tau}\right\}\theta_z$$

$$\text{or } \mathrm{Cos}\phi' = \mathrm{Cos}\phi\left\{1 - \left(x_2 - \frac{\tan\phi}{\tau}\right)\mathrm{Sin}\phi\mathrm{Cos}\phi\theta_z\right\}$$

where θ_z is the full load value of θ, when approximate values of the transformer numeric and of the secondary leakage coefficient are known.

[In future τ will be used for either τ_1 or τ_2 when approximate values only are required].

The approximate value of τ required may be found by a rough preliminary calculation, or from a formula such as that given in § 55, when τ for some other transformer of the same type is known, and θ_z, the full load value of ϕ, taken as given by the equation (see § 17),

$$\theta_z \text{Cos}\phi = \sqrt{\frac{z\text{Sin}\delta}{\text{T}}} = \sqrt{\frac{z\tau\text{Sin}\delta}{2}}$$

where z is the chosen ratio of copper to iron losses at full load.

In Section III. of this paper will be shown how to determine the leakage coefficients when the form of the magnetic circuit, method of winding, and space factors, are known. As these details will be decided on in the first place, a fairly accurate preliminary value of x_2 can be obtained, and hence the value of $\text{Cos}\phi'$ by means of either of the equations given above.

Thus we can obtain from equation I. above the product of the section of the iron circuit by the total section of the secondary copper circuit.

Obviously, as a first approximation we might in equation I. consider $P'_2 = P_2$ and $\text{Cos}\phi' = \text{Cos}\phi$, which would amount to neglecting secondary leakage and secondary copper loss.

A second relation between the two variables is obtained by expressing the condition that, at full load, the ratio of the copper to the iron losses is to have a definite chosen value z.

If z be chosen as unity for a transformer that is to operate a non-inductive load, or as

$$1 - \text{Sin}\phi\left\{x_2\text{Sin}\delta - \frac{\text{Cos}\delta}{\tau}\right\}\sqrt{\frac{2\tau}{\text{Sin}\delta}}$$

(using the approximate value of τ) for one that is to operate an inductive load whose power factor is $\text{Cos}\phi$, then in either case full load would correspond with maximum efficiency (see § 16).

As the efficiency of a transformer keeps very near its maximum value for a wide range on either side of the maximum position, it is not a matter of great importance to arrange that maximum efficiency exactly corresponds to full load.

As copper costs more than iron it may be more economical to use a relatively smaller quantity of copper, and put up with a larger copper loss than when $z = 1$.

From these two relations the two variables, and hence the dimensions of the transformer, are determined, and the formulae in Section I. enable us to arrive at the different details such as n_1, n_2, a_1, a_2, r_1, r_2, τ_1, τ_2, etc., when the e.m.f.'s on the primary and secondary sides are given.

28. As an illustration of this method I will work out the theoretical* design of transformer, to transform from 2200 to 220 virtual volts at 50 periods, and to carry an inductive load of 10 K.W. whose power factor is .8.

Selecting the shell type of transformer, one of the laminae of which is shaped as in Fig. 5, we will suppose the iron tongue to be of square cross section (2β, 2β) and the windows or winding apertures to be also square ($2b$, $2b$).†

Hence the mean length of the magnetic circuit is $4\ (2b+\beta)$, and the mean length of a turn of either primary or secondary coil (so wound as to be the same for both) is $8\ (b+\beta)$.

If p‡ the space factor of the iron be taken $=.9$, then the cross section of the iron circuit is $=4p\beta^2=3.6\beta^2$, and the volume of the iron

$$=16p\beta^2(2b+\beta)=14.4\beta^2(2b+\beta).$$

The space factor p will not only enable us to allow for insulation between the laminae, but also for ventilating or cooling ducts, if such are deemed necessary.

Let us decide that the iron loss shall be 10^5 ergs. per second, per unit volume.

With a sample of transformer iron .045 cm. thick I have found with my wave tracer,|| when the iron loss per cm.^3 per second was 10^5 ergs. at 50 periods, the magnetising current wave form being slightly peaked, that

$$\gamma=4800,\ \delta=52^\circ\ \mu=2250\ \text{(q.p.)}$$

so for the present design I will assume, for the iron to be used,

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* Called theoretical because the details are fully worked out in accordance with the theory already given. A knowledge of the theory and experience will, however, enable one to make sufficiently accurate allowance for most of the small correcting terms, instead of having to calculate them in each particular case.

† This is far from being the most efficient shape, as will be shown in Section III.

‡ The different factors and constants assumed are not given with any authority. The purpose of this [illegible] rel[illegible] [illegible]strative.

that

$\gamma = 4847,\ \delta = 50^\circ\ \mu = 2250,$

which satisfy the sine wave equation

$$\frac{w\gamma^2 \mathrm{Sin}\delta}{8\pi\mu} = 10^5$$

which states that the iron loss per cm.^{3} per second is 10^5 ergs.

The core loss will therefore be $144.10^4\beta^2(2b+\beta)$ at full load.

29. The kind of winding to be adopted will depend on the excellence of regulation for inductive loads that is required. In Section III. will be shown how to calculate the leakage coefficients for different kinds of windings, and how the regulation for inductive loads that these windings will give, may with considerable accuracy be predetermined.

A very important consideration with regard to the arrangement of the windings is clearly shown by the general expression for the efficiency given in § 15. It will be seen that in the denominator, positive terms depending on x_2, the leakage coefficient of the secondary, occur, of the first order in small quantities for inductive loads, and of the second order for non-inductive loads. Hence it is obvious that if we have a choice, we should so place the secondary windings or sections that x_2 is the least possible. Now it will be shown in Section III. that, with interleaved windings symmetrically arranged with regard to the middle line across the window, which line must therefore bisect the central section of one of the coils, the leakage coefficient of that coil to which the two outer sections belong is negative. Hence the most efficient arrangement is that in which the two outer sections belong to the secondary or output coil. The regulation will be the same whether one or other of the coils has the outer positions, as it depends on $x_1 + x_2$, which is little or not at all affected by the interchange.

Assuming that for the present design a winding in three sections will give satisfactory regulation, we will place the whole primary coil as a single section in the central position between the two halves of the secondary coil.

For such a winding, when the iron and copper losses per [illegible] and the space factors are as we assume in [illegible] design [illegible] when $\mu = 2250$ (see § 51),

$x_1 = .00129 \quad x_2 = -.00024$
$x_1 + x_2 = .00105.$

30. If K_1 and K_2 be the permissible copper losses per second per cm.^{3} at full load, K_1 for the primary being decided on as say 15.10^4 ergs, and K_2 differing from K_1 by a small amount which will depend on how the copper losses are to be divided between the two coils; then

$K_1 = \frac{1}{2}\rho c_1^2, \quad K_2 = \frac{1}{2}\rho c_2^2,$

where c_1 and c_2 are the amplitudes of the current densities, and ρ the specific resistance of copper at the expected working temperature.

Let us take $\rho = 1800$ abs.
then $\qquad c_1 = 12.91$ abs.

Let s_1, s_2, be the sectional areas, l_1, l_2 the mean turns, and q_1, q_2 the space factors of the two coils; so that $q_1 s_1$, $q_2 s_2$, are their total copper sections, and $q_1 s_1 l_1$, $q_2 s_2 l_2$, their total copper volumes; then (see § 6) since $l_1 = l_2$,

$$\frac{q_1 s_1}{q_2 s_2} = \frac{\tau_1}{\tau_2} = 1 + \kappa \text{ say},$$

where κ is a small quantity to be determined, depending on the current densities in the two coils at full load.

This equation, together with $s_1 + s_2 = 4b^2$, give us the copper sections,

$$q_1 s_1 = 2Qb^2\left\{1 + \frac{Q}{2q_2}\kappa\right\}$$

$$q_2 s_2 = 2Qb^2\left\{1 - \frac{Q}{2q_1}\kappa\right\}$$

where $Q = \dfrac{2q_1 q_2}{q_1 + q_2}$ = the harmonic mean of q_1 and q_2.

Let us assume for the copper space factors

$q_1 = .5, \quad q_2 = .7$

then $\quad Q = .583$

and $\quad q_1 s_1 = 1.166(1 + .42\kappa)b^2$

$\qquad q_2 s_2 = 1.166(1 - .58\kappa)b^2.$

31. If we arrange so that the current densities in the two coils shall be equal at full load, then

$c_1 = c_2, \quad K_1 = K_2$

and

$$\frac{q_1s_1}{q_2s_2}=\frac{n_1C_1}{n_2C_2}=1+\frac{\text{Sin}(\delta+\phi)}{\theta_z\text{Cos}\phi}\text{ (see § 13)}$$

$$\text{or }\kappa=\frac{\text{Sin}(\delta+\phi)}{\theta_z\text{Cos}\phi}$$

where C_1, C_2, and θ_z are full load values.

In addition let us arrange that the copper and iron losses shall be equal at full load. Then (see § 17), as $z=1$,

$$\theta_z\text{Cos}\phi=\sqrt{\frac{\text{Sin}\delta}{\text{T}}}=\sqrt{\frac{\tau\text{Sin}\delta}{2}}$$

so that

$$\kappa=\text{Sin}(\delta+\phi)\sqrt{\frac{2}{\tau\text{Sin}\delta}}.$$

For the determination of κ and other small correcting terms, an approximate value of τ must be known. We can easily obtain one by a rough preliminary calculation in which these correcting terms are neglected, or from the formula given in § 55, when τ for some other transformer of the same type is known.

The first method gives us $\tau=6000$;
hence as

$\delta=50°$, $\text{Sin}\delta=.766$,

$\text{Cos}\phi=.8$, $\phi=37°$,

we find that,

$\theta_z\text{Cos}\phi=48$, $\theta_z=60$,

$\kappa=.02$, $\tau_1/\tau_2=1.02$,

$\frac{\theta_z}{\tau}=.01$

and taking $x_2=-.00024$ (see § 28),

$\text{Cos}\phi'=.808$ at full load (see §§ 10, 27).

Substituting the value of κ thus determined in the expressions for q_1s_1, and q_2s_2 we get

$q_1s_1=1.176b^2$, $q_2s_2=1.153b^2$.

Hence, the total volume of copper being

$=l(q_1s_1+q_2s_2)=8(b+\beta)(q_1s_1+q_2s_2)$,

it is

$=18.63b^2(b+\beta)$,

and as the copper losses at full load are

$=15.10^4\times$ volume,

they are

$$=2795.10^8 b^2(b+\beta).$$

32. As we intend that the copper and iron losses shall be equal at full load,

$$\frac{2795 b^2(b+\beta)}{1440\beta^2(2b+\beta)}=1 \text{ (see §§ 28, 31).}$$

or $\dfrac{u+1}{u^2(u+2)}=.5152$

where $u=\beta/b$,

from which equation u (the positive root) can easily be determined by trial (using a slide rule) and is $=1.151$,

hence $\beta=1.151b$.

33. The output P_2, being 10 K.W., that is, 10^{11} ergs. per second, and (see § 13) as

$$P'_2=\left\{1+\frac{\theta_2}{\tau}\right\}P_2,$$

we find, using the approximate value for $\frac{\theta_2}{\tau}$ given in § 31, that P'_2, the total power developed in the secondary is

$$=1.01 \,.\, 10^{11},$$

but $P'_2=\frac{1}{2}E'_2C_2\text{Cos}\phi'$

$$=\tfrac{1}{2}wn_2FC_2\text{Cos}\phi';$$

hence, using the value of $\text{Cos}\phi'$ given in § 31, and remembering that $w=2\pi \,.\, 50=100\pi$,

$$n_2C_2F=\frac{202 \,.\, 10^9}{100\pi \,.\, .808},$$

$$=796 \,.\, 10^6.$$

Now c_2 being the permissible current density $=12.91$ (see § 30).

$$n_2C_2=c_2q_2s_2=12.91 \,.\, 1.153b^2$$

$$=14.9b^2$$

and γ being the permissible flux density $=4847$,

$$F=4p\beta^2\gamma=3.6 \,.\, 4847 \,.\, \beta^2,$$

$$=17450\beta^2.$$

Hence $b^2\beta^2=\dfrac{796 \,.\, 10^6}{14 [illegible] \,.\, [illegible]450}=3062$

and as $\beta=1$[illegible]

we find th[illegible]

which de[illegible]

Substituting these values of β and b in the expressions for the copper and iron losses at full load given in §§ 31, 28, we find that each is equal to $200.3 \, . \, 10^7$, that is to 200.3 watts.

Hence the efficiency at full (inductive) load of 10 K.W. will be

$$\frac{10000}{10400.6} \text{ or } 96.15 \text{ per cent.}$$

34. The numerics τ_1 and τ_2 can now be determined for as

$\tau_1 = 4\pi w \times$ Conductance of primary copper belt $\times$ Permeance of magnetic circuit

$$\tau_1 = 4\pi w \frac{q_1 s_1}{8(b+\beta)\rho} \frac{4p\beta^2\mu}{4(2b+\beta)}$$

$$= \frac{400 \, . \, \pi^2 \, . \, 1.176 \, . \, 48.08 \, . \, 3.6 \, . \, 63.7 \, . \, 2250}{8 \, . \, 14.91 \, . \, 1800 \, . \, 4 \, . \, 21.84},$$

$$= 6140,$$

and as $\tau_1 = 1.02\tau_2$,

$$\tau_2 = 6020.$$

From the results already obtained the accurate full load value of $\theta_z \text{Cos}\phi$ can now be calculated by means of the formula in § 17, remembering that $z=1$.

Thus we get at full load

$$\theta_z \text{Cos}\phi = 47.75.$$

35. To determine n_1 the number of primary turns, we have (see § 13),

$$w n_1 \text{F} = \frac{\text{M}}{\text{D}} \text{E}_1,$$

where M and D are the full load values of the expressions for them given in § 12. These can now be obtained as all the quantities required for their calculation are known.

Thus $\text{M}=1$, $\text{D}=1.044$,

and as

$$\text{F} = 17450\beta^2 = 1111.10^4 \text{ (see 33)},$$

$$\text{E}_1 = 2200 \, . \, 1.414 \, . \, 10^8,$$

$$w = 100\pi,$$

we find that $n_1 = 854$.

36. To determine n_2 the number of secondary turns, so that at full load the secondary e.m.f. shall be 220 volts.

From § 13,

$$E_2 = \frac{n_2}{n_1}\frac{E_1}{D}$$

$$\text{or } n_2 = \frac{n_1 D}{10}$$

and as D=1.044 (see § 35),

$n_2 = 89.16$.

37. The sectional area of the conductors to be used being

$$\frac{q_1 s_1}{n_1} \text{ and } \frac{q_2 s_2}{n_2},$$

for the primary and secondary respectively, we find (see §§ 31, 33),

Sect. area of primary conductor $=0.0662 cm^2$,

Sect. area of secondary conductor $=0.6218 cm^2$.

The mean length of a turn of either coil being

$=8(b+\beta)=119.3$

and as $\rho=1800$,

the resistances of the coils (warm) are

Primary, 2.77 ohms.

Secondary, 0.0308 ohms.

38. The terminal voltage at no load being (see § 13)

$$\frac{n_2}{n_1}\frac{E_1}{1+x_1\text{Cos}\delta+\frac{\text{Sin}\delta}{\tau_1}}$$

is $=229.5$ volts,

and as it is 220 volts at full inductive load the drop will be 4.14 per cent.

If the same transformer operated a non-inductive load it would be rated as of

$$\frac{10}{.8} = 12.5 \text{ K.W. capacity,}$$

and its voltage drop from no load to a non-inductive load of 12.5 K.W. would be 1.5 per cent.

39. By means of the formulae obtained in Section I. the curves shown in Fig. 3 and Fig. 4 were constructed for the

transformer we have designed. Those in Fig. 3 refer to it when operating the kind of load for which it was designed, namely, one with a constant power factor of .8, while those in Fig. 4 refer to the same transformer when operating a non-inductive load. A comparison of these theoretical curves with similar ones obtained practically from actual transformers will afford a further illustration of the agreement between the theory I have given and practice.

40. In the preceding design it was arranged that the current densities in the two coils should be equal at full load. Any other desired distribution of current density, however, can be equally well dealt with.

Thus if K_1 and K_2, the copper losses per cm^3 at full load, be each given, we know c_1 and c_2 as $K = \frac{1}{2}\rho c^2$, and

$$\frac{q_1 s_1 c_1}{q_2 s_2 c_2} = \frac{n_1 C_1}{n_2 C_2} = 1 + \kappa$$

κ is determined as in § 30, by aid of an approximate value of τ, so that the ratio

$\frac{q_1 s_1}{q_2 s_2}$ can be found;

and as $s_1 + s_2 = 4b^2$ we can determine s_1 and s_2 and proceed as before.

Again if K_1 be given, and we wish to arrange so that at full load the primary and secondary copper losses shall be equal, we have

$$\frac{q_1 s_1 c_1}{q_2 s_2 c_2} = 1 + \kappa \qquad \text{(as above)},$$

and $q_1 s_1 l_1 K_1 = q_2 s_2 l_2 K_2$

or $\quad q_1 s_1 c_1^2 = q_2 s_2 c_2^2$

as $l_1 = l_2$ and $K = \frac{1}{2}\rho c^2$

hence $\frac{q_1 s_1}{q_2 s_2} = (1 + \kappa)^2$,

which with $s_1 + s_2 = 4b^2$

determine s_1 and s_2 and we proceed as before.

In transformers of the core or H type, in which the primary coil almost completely surrounds the secondary, l_1 is greater than l_2, and the preceding method would have to be modified.

When s_1 and s_2 have been determined as before, l_1 and l_2 can be expressed in terms of the two variables b and β, and the ratio of the losses

$$\frac{q_1 s_1 l_1 K_1 + q_2 s_2 l_2 K_2}{I \text{ (volume of iron)}}$$

being equated to the selected value z gives us an equation, slightly more complex than that for a shell transformer, for determining β/b and the rest follows as in the preceding cases.

41. When we select for the section of the iron tongue and for the windows or winding apertures different shapes from that selected in § 28, the method of procedure is fairly obvious. In general if 2β, $2\beta'$, be the section of the tongue, $2\beta'$ being measured perpendicular to the planes of the laminae; and if $2b$, $2b'$, be the dimensions of the window $2b'$ being measured parallel to the tongue;

the volume of iron $\quad = 16p\beta\beta'(b+b'+\beta)$
and the volume of copper $= 16Qbb'(\beta+\beta'+2b)$
[neglecting the small correcting terms in κ depending on the distribution of current densities in the two coils], where p and Q have the same signification as before, and if the iron and copper losses are to be equal at full load

$$\frac{bb'(\beta+\beta'+2b)}{\beta\beta'(b+b'+\beta)} = \frac{pI}{QK} = \frac{.9 \;.\; 10^5}{.583 \;.\; 15 \;.\; 10^4} = 1.029$$

if we adopt the same values for the data as before.

The values of β/b for a few special shapes are as follows :—

(*a*) If $b=b'$, $2\beta'=3\beta$,
$\beta/b=.984$.

(*b*) If $b=b'$, $\beta'=2\beta$,
$\beta/b=.886$.

(*c*) If $2b'=3b$, $2\beta'=3\beta$,
$\beta/b=1.141$.

(*d*) If $2b'=3b$, $\beta'=2\beta$,
$\beta/b=1.025$.

(*e*) If $b'=2b$, $2\beta'=5\beta$,
$\beta/b=1.042$.

Let us determine approximate values of τ for transformers of the above shapes whose output on non-inductive load shall be 12.5 K.W. at 50 periods, the normal rating of the transformer already designed.

We have (see § 33)

$\frac{1}{2}wn_2C_2F=12.5 \,.\, 10^{10}+$Secondary copper loss, and the secondary copper loss may in this connection be neglected in a rough determination of τ; but

$$n_2C_2=c_2 \,.\, \frac{Q}{2} \,.\, 4bb'=15.05bb',$$

$$F=\gamma \,.\, p \,.\, 4\beta\beta'=17450\beta\beta',$$

taking the values $c_2=12.91$, $\gamma=4847$ already used; hence

$$bb'\beta\beta'=\frac{12.5 \,.\, 10^{10}}{50\pi \,.\, 15.05 \,.\, 17450}=3030,$$

which with the ratios β/b above enables us to determine β and b in each case.

The formula for the numeric τ can be put in the form

$$\tau=\frac{\pi\mu}{2\rho c\gamma}\frac{\text{Output}}{(\beta+\beta'+2b)\,(b\pm b'+\beta)}=\frac{3{,}925{,}000}{(\beta+\beta'+2b)\,(b+b'+\beta)}$$

by means of which its values in the five special cases considered can be determined.

Thus we obtain the following details given in tabular form.

	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)
b	6.76	6.63	5.67	5.57	4.86
b'	6.76	6.63	8.50	8.35	9.72
β	6.65	5.87	6.47	5.71	5.06
β'	9.97	11.74	9.70	11.42	12.65
Volume of copper	12840	12660	12450	12280	12090
Volume of iron	19250	18990	18680	18420	18140
τ	6460	6650	6910	7080	7280

We also find that the iron losses at full load, which are half the total losses, are for (*a*) 192.5, (*b*) 189.9, (*c*) 186.8, (*d*) 184.2, and (*e*) 181.4 watts, so that transformer (*e*) is the most efficient of the series, having an efficiency at full load of 97.2 per cent. Obviously the transformer designed in detail with square windows and square tongue is of a less efficient shape than any of these, as its iron loss at full load is 200.3 watts.

The volume of iron in each of the present series in cub. cms. is 100 times the iron loss in watts. In (*e*) it is 18140 cub. cms.,

which corresponds to 25 lbs. of iron core for each kilowatt of full load activity.

It is worth noting that, for transformers of the same type made of similar iron, the percentage iron and copper losses and the weights of copper and iron per kilowatt of full load activity, are inversely proportional to the fourth root of the product of the output into the frequency.

SECTION III.

TRANSFORMER LEAKAGE.

42. In addition to the magnetic lines forming the main flux $\overline{F}$, produced by the combined action of $\overline{C}_1$ and $\overline{C}_2$ and looped on both circuits of a transformer, there are other lines, the leakage lines, that are only partially looped on the two coils and that traverse the space occupied by the coils, in some cases completing their circuits in the iron. It will be shown that, after the transformer is somewhat loaded, the effect of these leakage lines on its operation is the same as would be produced by two fluxes; one, the primary leakage flux, supposed to consist of lines in phase with the primary current that are looped on the primary and miss the secondary circuit, and the other, the secondary leakage flux, suppposed to consist of lines in phase with the secondary current, that are looped on the secondary and miss the primary circuit.

43. Let L_1 and L_2 be the inductances of the two coils when the leakage lines only are considered, M_{12} the mutual inductance of the primary on the secondary, that is the number of leakage lines looped on the secondary arising from unit current in the primary, and M_{21} the mutual inductance of the secondary on the primary. (M_{12} will not in general be equal to M_{21}).

The e.m.f. $\overline{e}_1$ generated in the primary coil by variation of the leakage lines due to $\overline{C}_1$ and $\overline{C}_2$ will be represented by the vector

$$\overline{wL_1C_1 + wM_{21}C_2}$$

after it has been turned through a right angle in the negative direction: but since the vector

$$\overline{n_1C_1 + n_2C_2}$$

which represents the magnetising ampere turns, is, after the

transformer is somewhat loaded, negligible in comparison with either $\overline{n_1C_1}$ or $\overline{n_2C_2}$ (see §§ 9, 13, 25, 26),

$$\overline{C}_2 = -\frac{n_1}{n_1}\overline{C}^1$$

and hence $\bar{e}_1$ is the vector

$$w\left\{\frac{L_1}{n_1} - \frac{M_{21}}{n_2}\right\}n_1\overline{C}_1,$$

after it has been turned back through a right angle and

$$\text{amp. } e_1 = w\left\{\frac{L_1}{n_1} - \frac{M_{21}}{n_2}\right\}n_1C_1$$

Thus we see that the effect of the leakage lines on the primary circuit is the same, when the transformer carries a load, as would be produced by a flux

$$= \left\{\frac{L_1}{n_1} - \frac{M_{21}}{n_2}\right\}\overline{C}_1$$

looped on it but not on the secondary; but in § 2 this flux was specified by $x_1\sigma n_1\overline{C}_1$

where x_1 is the primary leakage coefficient, and σ is 4π times the permeance of the magnetic circuit, hence

$$x_1 = \frac{1}{n_1\sigma}\left\{\frac{L_1}{n_1} - \frac{M_{21}}{n_2}\right\}.$$

Similarly if x_2 be the secondary leakage coefficient

$$x_2 = \frac{1}{n_2\sigma}\left\{\frac{L_2}{n_2} - \frac{M_{12}}{n_1}\right\}.$$

44. Let us determine L_1, L_2, M_{12}, M_{21} and thence x_1 and x_2 for a shell transformer in which both primary and secondary coils are single.

This must be done in two parts. We must determine the values of those portions of the above coefficients that are due to the leakage lines that cross the windows, as well as the values of their remaining portions that are due to the leakage lines that cross those parts of the coils that are not embedded in the iron. Let L'_1, L'_2, M'_{12}, M'_{21}, x'_1, x'_2 be the former, and L''_1, L''_2, etc., the latter portions of the above coefficients.

Let 2β be the width of the iron tongue measured in the plane of one of the laminae from window to window, and let $2\beta'$ be its height measured perpendicular to the laminae. Also (see Fig. 5) let PP′ the breadth of the window $=$ D, PO the thickness

of the primary coil$=b_1$, and SO the thickness of the secondary coil$=b_2$.

In order to determine L'_1, L'_2, etc., consider first the leakage lines *produced by* C_1 that cross the windows through the spaces occupied by the primary coil.

If we draw two planes A′A, B′B, Fig. 5, the same distance z on either side of the median plane of the primary, the magnetic forces due to the two portions of the primary coil AP and BO neutralize each other within the space AA′BB′, so that the M.M.F. round the circuit A′ABB′ is due to the portion of the primary it encloses and is

$$=\frac{8\pi n_1 C_1}{b_1} z,$$

and the flux circulating in this circuit through the elemental rectangle $2\beta' dz$ at z is

$$=\frac{8\pi\beta'}{Db_1} n_1 C_1 z dz$$

as it crosses the window twice.

This flux encircles the current

$$\frac{n_1 C_1}{b_1} 2z$$

and as the energy associated with naturally looped flux and current is $\frac{1}{2}$ flux $\times$ current, the energy of C_1 due to the lines through the space occupied by the primary coil is

$$=\frac{8\pi\beta'}{Db_1^2} n_1^2 C_1^2 \int_{0'}^{\frac{b_1}{2}} z^2 dz$$

$$=\frac{\pi}{6}\,\frac{2\beta' b_1}{D} n_1^2 C_1^2 \qquad \text{(I.)}$$

Thus we see that the energy of C_1 due to the leakage lines that cross and recross the space occupied by the coil carrying C_1 is equal to $\frac{\pi}{6}\, n_1^2 C_1^2 \times$ permeance of this space across the window.

Again the M.M.F. due to C_1, in any circuit that crosses the space occupied by the secondary coil, and completes itself through the iron round the primary coil is uniform, and $=4\pi n_1 C_1$ and sends through the secondary space (section $2\beta' b_2$) the flux

$$\frac{8\pi\beta' n_1 C_1}{D} b_2$$

(neglecting the reluctance of the iron).

This flux encircles all of n_1C_1 and the energy associated with it is

$$\frac{4\pi\beta'}{D} n_1^2 C_1^2 b_2,$$

so that the total energy of C_1 due to the leakage lines it produces and that cross the window is

$$= \frac{4\pi\beta'}{D}\left\{b_2 + \frac{b_1}{12}\right\} n_1^2 C_1^2.$$

The other window contributes an equal amount, hence as the sum is also equal to $\frac{1}{2}L'_1C^2$,

$$\left.\begin{array}{l} L'_1 = \dfrac{16\pi\beta'}{D}\left\{b_1 + \dfrac{b_1}{12}\right\} n_1^2. \\ \text{Similarly,} \\ L'_2 = \dfrac{16\pi\beta'}{D}\left\{b_1 + \dfrac{b_2}{12}\right\} n_2^2. \end{array}\right\} \quad \text{(II.)}$$

The latter of the two fluxes already considered is partially looped on n_2C_2 and the mutual energy of C_1 and C_2 due to this can easily be found as follows.

The flux through $2\beta' dy$ where y=OE, Fig. 5, is

$$= 4\pi n_1 C_1 \frac{2\beta' dy}{D},$$

and it is looped on the portion

$$\frac{n_2C_2}{b_2} y \text{ of } n_2C_2$$

so that the mutual energy is

$$= \frac{8\pi\beta'}{Db_2} n_1 n_2 C_1 C_2 y dy.$$

Integrating from $y=o$ to $y=b_2$ we find that the mutual energy of C_2 and the leakage lines due to C_1 is

$$= \frac{4\pi\beta'}{D} n_1 n_2 C_1 C_2 b_2.$$

Thus we see that the mutual energy of the uniform C_1 flux that goes through the C_2 coil, and n_2C_2 is

$$= \tfrac{1}{2} \text{ . flux . } n_2C_2. \qquad \text{(III.)}$$

or is the same as if all the flux through the space were looped on half the total current in the space, a result that will be made use of in § 45, *b*.

Hence, as the other window contributes an equal amount of energy

$$\left.\begin{aligned} M'_{12}C_1C_2 &= \frac{8\pi\beta'}{D}n_1n_2C_1C_2b_2 \\ M'_{12} &= \frac{8\pi\beta'}{D}n_1n_2b_2. \\ \text{Similarly,} & \\ M'_{21} &= \frac{8\pi\beta'}{D}n_1n_2b_1. \end{aligned}\right\} \quad \text{(IV.)}$$

Substituting from (II.) and (IV.) in the equations for x'_1 and x_2 in § 43, we get

$$\left.\begin{aligned} x'_1 &= \frac{16\pi\beta'}{\sigma D}\left\{b_2 - \frac{5}{12}b_1\right\} \\ x'_2 &= \frac{16\pi\beta'}{\sigma D}\left\{b_1 - \frac{5}{12}b_2\right\} \\ \text{and} & \\ x'_1 + x'_2 &= \frac{28\pi\beta'}{3\sigma D}\left\{b_1 + b_2\right\} \end{aligned}\right\} \quad \text{(V.)}$$

45. The determination of the coefficients x''_1 and x''_2 due to leakage lines other than those that cross the windows can only be approximate.

A fair approximation can, however, be obtained by assuming that these lines form circuits like $aa'cb'ba$, Fig. 6, of which ba is in the iron, as the inner surfaces of the coils bear against the iron tongue, aa' and bb' are parallel to the plane of separation of the coils and $a'cb'$ is a semicircle in the air joining a' and b'.

Let us consider the lines due to C_1.

If aa' and bb' are a distance z on either side of the median plane of the primary coil, then the M.M.F. round the circuit $aa'cb'ba$ is

$$= \frac{4\pi n_1 C_1}{b_1} 2z,$$

which will send through the magnetic circuit at z, whose breadth is dz the flux

$$\frac{4\pi n_1 C_1}{b_1} 2z \frac{B\,dz}{2D + \pi z}$$

if B be the mean width perpendicular to dz of this elementary circuit. Now where the coil bears against the iron the width is

2β, and at the outer surface of the coil the width is $2\beta + \pi D$, if we assume that the corners of the coil are quadrants of circles.

Hence $B = 2\beta + \frac{\pi}{2}D$.

[This allowance for the corners of the coil may be considered rather large, but if so it is compensated by the fringing of the lines crossing the windows, which has not been allowed for.]

Adding an equal amount for the other uncovered side of the coil, the flux across dz due to C_1 is

$$\frac{16B}{b_1} n_1 C_1 \frac{z\,dz}{z + \frac{2D}{\pi}},$$

and it is looped on

$$\frac{n_1 C_1}{b_1} 2z \text{ of } n_1 C_1,$$

so that the energy associated with it is

$$\frac{16B}{b_1^2} n_1^2 C_1^2 \frac{z^2 dz}{z + \frac{2D}{\pi}}$$

Integrating this between the limits $z = b_1/2$ and $z = 0$ we get

$$4Bn_1^2C_1^2\left\{\tfrac{1}{8} - 2\lambda_1 + 4\lambda_1^2 \log\frac{1 + 2\lambda_1}{2\lambda_1}\right\}, \qquad \text{where } \lambda_1 = \frac{2D}{\pi b_1}$$

which is the energy of C_1 due to its lines through the primary coil.

Again the energy of C_1 due to the lines it sends through the space occupied by the secondary coil is

$$= 4Bn_1^2C_1^2 \int_{\frac{b_1}{2}}^{\frac{b_1}{2} + b_2} \frac{dy}{y + \frac{2D}{\pi}}$$

$$= 4Bn_1^2C_1^2 \log\frac{1 + 2\lambda_1 + 2\nu_1}{1 + 2\lambda_1}$$

where $\nu_1 = \frac{b_2}{b_1}$.

The sum of these two results being $\frac{1}{2}L''_1 C_1^2$

$$L''_1 = 8Bn_1^2\left\{\tfrac{1}{2} - 2\lambda_1 + 4\lambda_1^2 \log\frac{1 + 2\lambda_1}{2\lambda_1} + \log\frac{1 + 2\lambda_1 + 2\nu_1}{1 + 2\lambda_1}\right\}.$$

Similarly, if $\lambda_2 = \frac{2D}{\pi b_2}$, $\nu_2 = \frac{b_1}{b_2} = \frac{1}{\nu_1}$

$$L''_2=8Bn_2^2\left\{\tfrac{1}{2}-2\lambda_2+4\lambda_2^2\log\frac{1+2\lambda_2}{2\lambda_2}+\log\frac{1+2\lambda_2+2\nu_2}{1+2\lambda_2}\right\}$$

In a like manner we find that

$$M''_{12}=8Bn_1n_2\left\{1-(\lambda_2+\tfrac{1}{2}\nu_2)\log\frac{1+2\lambda_1+2\nu_1}{1+2\lambda_1}\right\}$$

$$M''_{21}=8Bn_1n_2\left\{1-(\lambda_1+\tfrac{1}{2}\nu_1)\log\frac{1+2\lambda_2+2\nu_2}{1+2\lambda_2}\right\}$$

and substituting in the equations for x_1 and x_2 in § 43

$$x''_1=\frac{8B}{\sigma}\left\{-\tfrac{1}{2}-2\lambda_1+4\lambda_1^2\log\frac{1+2\lambda_1}{2\lambda_1}+\log\frac{1+2\lambda_1+2\nu_1}{1+2\lambda_1}+\right.$$
$$\left.(\lambda_1+\tfrac{1}{2}\nu_1)\log\frac{1+2\lambda_2+2\nu_2}{1+2\lambda_2}\right\}$$

$$x''_2=\frac{8B}{\sigma}\left\{\text{Interchange } \lambda_1 \text{ and } \lambda_2,\ \nu_1 \text{ and } \nu_2 \text{ in above.}\right\}$$

and finally for the leakage coefficients of the transformer

$$x_1=x'_1+x''_1$$
$$x_2=x'_2+x''_2.$$

46. From the expressions in §§ 44, 45, let us determine x_1 and x_2 for transformers with square windows and iron tongue of square cross section, and of which the secondary coil occupies three-fourths as much space as is occupied by the primary.

Then $D=b_1+b_2,\ b_1=\frac{4}{7}D,\ b_2=\frac{3}{7}D,$

$$\beta=\beta',\ \nu_1=3/4,\ \nu_2=4/3,$$
$$\lambda_1=\frac{2D}{\pi b_1}=1.11,\ \lambda_2=\frac{2D}{\pi b_2}=1.48$$

From § 44 we get

$$x'_1=9.6\frac{\beta}{\sigma},\quad x'_2=19.8\frac{\beta}{\sigma},$$

and from § 45

$$x''_1=2\frac{B}{\sigma},\quad x''_2=\frac{7}{2}\frac{B}{\sigma}.$$

Remembering that $B=2\beta+\frac{\pi}{2}D$, we find that

$$x_1=x'_1+x''_1=\frac{13.6\beta+3.1D}{\sigma},$$

$$x_2=x'_2+x''_2=\frac{26.8\beta+5.5D}{\sigma}.$$

As $\sigma=4\pi\mu\,.\,\dfrac{4\beta^2}{4(\beta+D)}$,

and as, in a transformer shaped as we have supposed 2β will be very nearly 1.2 D,

$$x_1 = \frac{4}{\mu}, \quad x_2 = \frac{7.6}{\mu}.$$

If we take $\mu = 2250$,

$$x_1 = .00178, \quad x_2 = .00338$$

$$x_1 + x_2 = .005$$

which in a 10 K.W. 50 period transformer, $\tau = 6000$, would give a drop on non-inductive load of 4.3 per cent., and on an inductive load of .8 power factor a drop of 18 per cent. approximately.

[Take $\tau_1 = \tau_2 = \tau$, $y = \sqrt{\frac{\tau \mathrm{Sin}\delta}{2}}$, $\mathrm{Sin}\delta = .75$, in formula in § 23 for a rough estimate of the drop].

47. In order to determine x_1 and x_2 for a shell transformer with interleaved windings we have, as before, to determine x'_1 and x'_2 due to the lines that cross the windows, and x''_1, x''_2, due to the remaining leakage lines, separately. We will first determine x'_1 and x'_2 in the general case. Let the sections of the two coils be arranged, as in Fig. 7, symmetrically, with regard to the median plane across the window so that a section of one of the coils occupies the central position in the window. Let the coil to which the central section belongs be called the even coil and its sections the even sections, and let the other coil be called the odd coil and its sections the odd sections. The even coil will have an odd number, i say, of sections, and the odd coil will have an even number, j say, of sections where j may be equal to either $i-1$ as in Fig. 7, or to $i+1$, in which case the two outer sections would be odd ones. Let b_2 be the thickness of each of the even sections and b_1 that of each of the odd ones; and let L_2, x_2, n_2, C_2 refer to the even coil and L_1, x_1, n_1, C_1, etc., to the odd one. Let 2β, $2\beta'$, be the section of the iron tongue, $2\beta'$ being measured perpendicular to the laminae; and let D be the breadth of the window.

In Fig. 7 is a diagram of the window in which the sections are numbered in accordance with the above plan, the central section being numbered O, and directly below is what we may call the M.M.F. diagram for C_2 in which the zig-zag line

OP gives the distribution of M.M.F. in the different sections due to C_2.

Thus if the M.M.F. round the Central section O, that is $\frac{4\pi n_2 C_2}{i}$, be called m_2,

the M.M.F. round the magnetic circuit 1, 1′, is m_2,
the M.M.F. round the magnetic circuit 3, 3′ is $3m_2$,
and so on, so that the ordinate of OP opposite any odd section is proportional to the number of the section. And it is easily seen that the mean ordinate of OP opposite any even section is also proportional to the number specifying that section.

The flux per unit length across the window at any point in OQ is

$$=\text{M.M.F.}\frac{2\beta'}{2\text{D}}$$

and if $m_2\frac{\beta'}{\text{D}}$ *i.e.* $\frac{4\pi n_2 C_2}{i}\,\frac{\beta'}{\text{D}}=f_2$

it is easy to see that, due to C_2,

the total flux round the circuit 1, 1′, is $f_2 b_1$
" " " " " " 2, 2′, is $2f_2 b_2$
" " " " " " 3, 3′, is $3f_2 b_1$

and so on.

(*a*) The energy of C_2 due to the leakage lines it sends through the even (its own) sections is, as we neglect the reluctance of the iron, the same as if the odd sections were removed and the even ones pushed up together.

By § 44, (I.), this energy is

$$=\frac{\pi}{6}\;\frac{2\beta' i b_2}{\text{D}}\;n_2^2 C_2^2. \qquad \text{(I.)}$$

The energy of C_2, due to the leakage lines it sends through the odd sections, is, by aid of Fig. 7, found to be

$$=\tfrac{1}{2}f_2 b_1\frac{n_2 C_2}{i}\left\{1^2+3^2+5^2+\quad+\overline{j-1}^2\right\}.$$

$$=\frac{2\pi\beta'}{\text{D}}\,\frac{n_2 C_2^2}{i^2}\;b_1\,\frac{j(j^2-1)}{6} \qquad \text{(II.)}$$

This follows easily when it is noticed, Fig. 7, that the flux $3f_2 b_1$ (for instance) round 3, 3′ is looped on three even sections, *i.e.*, on the current $3n_2C_2/i$, and similarly for the others.

Adding I. and II. we get the energy of C_2, due to the leakage lines it sends across one window. The other window contributes an equal amount, hence,

$$\tfrac{1}{2} L'_2 C_2^2 = \frac{2\pi\beta'}{3D} n_2^2 C_2^2 \left\{ i b_2 + \frac{j(j^2-1)}{i^2} b_1 \right\},$$

or

$$L'_2 = \frac{4\pi\beta'}{3D} n_2^2 \left\{ i b_2 + \frac{j(j^2-1)}{i^2} b_1 \right\}. \qquad \text{(III.)}$$

(*b*) The mutual energy of C_2 and C_1, due to the C_2 lines through the even spaces being looped on C_1, can be read off from Fig. 7, and is

$$= f_2 b_2 \frac{n_1 C_1}{j} \left\{ 2^2 + 4^2 + 6^2 + \quad + \overline{i-1}^2 \right\}$$

$$= \frac{2\pi\beta'}{3D} n_1 n_2 C_1 C_2 \frac{i^2-1}{j} b_2. \qquad \text{(IV.)}$$

The mutual energy of C_2 and C_1, due to the C_2 lines through the odd spaces being looped on C_1 is

$$= f_2 b_2 \frac{n_1 C_1}{j} \left\{ 1^2 + 3^2 + 5^2 + \quad + \overline{j-1}^2 \right\}$$

$$= \frac{2\pi\beta'}{3D} n_1 n_2 C_1 C_2 \frac{j^2-1}{i} b_1. \qquad \text{(V.)}$$

[This will be seen by considering circuit 3, 3′. The flux round it is $3 f_2 b_1$, and it completely encircles the two odd C_1 sections 1 and 1′, and partially the C_1 windings in 3 and 3′. But in § 44, III., it was shown that the mutual energy due to a uniform flux encircling a uniformly distributed current occupying the same space, was the same as if the whole flux encircled half the current; hence, in this case, the energy contributed by 3 and 3′ is the same as if the flux $3 f_2 b_1$ encircled one only of them completely, so that altogether the flux $3 f_2 b_1$ encircles $3 n_1 C_1 / j$ of the current C_1.]

Adding IV. and V., and doubling the sum to allow for the other window,

$$M'_{12} C_1 C_2 = \frac{4\pi\beta'}{3D} n_1 n_2 C_1 C_2 \left\{ \frac{i^2-1}{j} b_2 + \frac{j^2-1}{i} b_1 \right\},$$

$$\text{or } M'_{12} = \frac{4\pi\beta'}{3D} n_1 n_2 \left\{ \frac{i^2-1}{j} b_2 + \frac{j^2-1}{i} b_2 \right\} \qquad \text{(VI.)}$$

(*c*) In a similar manner, by aid of the M.M.F. diagram for C_1 also given in Fig. 7, or from symmetry we find that

$$\left.\begin{aligned} L'_1 &= \frac{4\pi\beta'}{3D} n_1^2 \left\{ jb_1 + \frac{i(i^2-1)}{j^2} b_2 \right\} \\ M'_{21} &= \frac{4\pi\beta'}{3D} n_1 n_2 \left\{ \frac{j^2-1}{i} b_1 + \frac{i^2-1}{j} b_2 \right\} \\ &= M'_{12} \end{aligned}\right\} \text{VII.}$$

(*d*) Substituting the values for L'_2, L'_1, M'_{12}, M'_{21}, in V., VI., and VII. in the expressions for x'_2 and x'_1 in § 43 we find

I. If the two extreme sections in the window are even ones, in which case $j=i-1$, that

$$x'_2 = -\frac{4\pi\beta'}{3\sigma D}\left\{ b_2 + \frac{i-2}{i} b_1 \right\},$$

$$x'_1 = \frac{4\pi\beta'}{3\sigma D}\left\{ \frac{i+1}{i-1} b_2 + b_1 \right\},$$

$$x'_2 + x'_1 = \frac{8\pi\beta'}{3\sigma D}\,\frac{H}{i(i-1)},$$

where $H = ib_2 + (i-1)b_1$

$= $ total height of window.

II. If the two extreme sections in the window are odd ones, in which case $j=i+1$,

$$x'_2 = \frac{4\pi\beta'}{3\sigma D}\left\{ b_2 + \frac{i+2}{i} b_1 \right\},$$

$$x'_1 = -\frac{4\pi\beta'}{3\sigma D}\left\{ \frac{i-1}{i+1} b_2 + b_1 \right\}$$

$$x'_2 + x'_1 = \frac{8\pi\beta'}{3\sigma D}\,\frac{H}{i(i+1)}$$

(*e*). From the results in (*d*) we see

I. That the coefficient x'_2 or x'_1 of the coil to which the two extreme sections belong is negative, indicating that this part of the leakage produces on the coil, with the extreme sections, a capacity and not an inductive effect.

The same thing is true with regard to the coefficients x''_2 and x''_1 due to the leakage lines that do not cross the windows and which will be determined in the next paragraph, and it has been pointed out in § 29 that secondary leakage reduces the efficiency of the transformer when operating inductive loads, hence the winding of a shell transformer for inductive work should be so arranged that the two extreme sections belong to the secondary or output coil.

II. That the sum $x'_1+x'_2$ of the coefficients due to the leakage lines crossing the windows is inversely proportional to the product of the numbers of sections in the two coils.

(*f*). If $2b=D$ be the breadth, and $2b'$ the height of the window, 2β, $2\beta'$ the section of the iron tongue as before, q_1 and q_2 the space factors of the coils; and μ the permeability of the iron; the formulae in (*d*) can be put in the following forms suitable for calculation.

$$x'_2=\frac{b'(b+b'+\beta)}{3\mu b\beta}\,\frac{\frac{q_1+2q_2}{q_1+q_2}\mp i}{i(i\mp1)}$$

$$x'_1=\frac{b'(b+b'+\beta)}{3\mu b\beta}\,\frac{\frac{q_1}{q_1+q_2}\pm i}{i(i\mp1)}$$

$$x'_2+x'_1=\frac{b'(b+b'+\beta)}{3\mu b\beta}\,\frac{2}{i(i\mp1)}$$

where the upper signs are to be taken when the two extreme sections belong to coil 2 (the even coil), of i sections, to which the middle section belongs, and the lower signs, when the extreme sections belong to coil 1.

Evidently $i\mp1$ is the number of sections of coil 1.

48. When we make the same assumption as is made in §45 with regard to the paths taken by the leakage lines that do not cross the windows, we can obtain the values of the coefficients x''_1, x''_2 due to these lines in the general case of interleaved windings.

Specifying the coils, sections, and dimensions of the transformer exactly as in the preceding paragraph, and letting

$$B=2\beta+\frac{\pi}{2}D=2\beta+\pi b \quad \text{(see § 47 } f\text{).}$$

$$\lambda_2=\frac{2D}{\pi b_2},\quad \lambda_1=\frac{2D}{\pi b_1},$$

$$\nu_2=\frac{b_1}{b_2},\quad \nu_1=\frac{b_2}{b_1},$$

we find, after proceeding as in §§ 45, 47, that

$$x''_2=\frac{32B}{\sigma}\Big[-\frac{1}{8}-\frac{1}{8}\nu_2\left(1-\frac{1}{i^2}\right)-\frac{\lambda_2}{2i}+\frac{\lambda_2^2}{i^2}\log\frac{1+2\lambda_2}{2\lambda_2}+$$

$$\sum_{n=2}^{n=i-1}\left\{\left(\frac{\frac{1}{2}n\nu_2+\lambda_2}{i}\right)^2+\frac{n(\frac{1}{2}n\nu_2+\lambda_2)}{2ij}\right\}\log\frac{2\lambda_2+n(1+\nu_2)+1}{2\lambda_2+n(1+\nu_2)-1}$$

$$+\sum_{m=1}^{m=j-1}\left\{\frac{m^2}{4i^2}+\frac{m(\frac{1}{2}m\nu_1+\lambda_1)}{2ij}\right\}\log\frac{2\lambda_1+m(1+\nu_1)+1}{2\lambda_1+m(1+\nu_1)-1}\Bigg]$$

$$x''_1=\frac{32\mathrm{B}}{\sigma}\Bigg[-\frac{1}{8}-\frac{\nu_1}{8}-\frac{\lambda_1}{2j}+$$

$$\sum_{n=2}^{n=i-1}\left\{\frac{n(\frac{1}{2}n\nu_2+\lambda_2)}{2ij}+\frac{n^2}{4j^2}\right\}\log\frac{2\lambda_2+n(1+\nu_2)+1}{2\lambda_2+n(1+\nu_2)-1}$$

$$+\sum_{m=1}^{m=j-1}\left\{\frac{m(\frac{1}{2}m\nu_1+\lambda_1)}{2ij}+\left(\frac{\frac{1}{2}m\nu_1+\lambda_1}{j}\right)^2\right\}\log\frac{2\lambda_1+m(1+\nu_1)+1}{2\lambda_1+m(1+\nu_1)-1}\Bigg].$$

where, in each of the above expressions, the values to be given to n are all the even numbers from 2 to $i-1$, and to m all the odd numbers from 1 to $j-1$ inclusive.

It will be easily seen, by considering the case of a winding with three sections, that by spreading out the free ends of the sections as is done for cooling purposes the values of the coefficients x''_1 and x''_2 will be slightly increased.

49. If the results in § 48 be written

$$x''_2=\frac{\mathrm{B}}{\sigma}\mathrm{X}_2=\frac{(2\beta+\pi b)\,(b+b'+\beta)}{4\pi\mu\beta\beta'}\mathrm{X}_2$$

$$x''_1=\frac{\mathrm{B}}{\sigma}\mathrm{X}_1=\frac{(2\beta+\pi b)\,(b+b'+\beta)}{4\pi\mu\beta\beta'}\mathrm{X}_1$$

it is easily seen that X_1 and X_2 depend only on the shape of the window, the numbers of sections of the two coils, and the ratio of their space-factors. In the following table are given the values of X_2 and X_1 for some different values of i and j, for square windows and for oblong ones whose height, measured parallel to the iron tongue, is twice their breadth ($2b'=4b$), and for some different ratios of space-factors.

It will be noticed in the following table that the coefficient of the coil to which the extreme sections belong is negative, and that the sum of X_1 and X_2 is (q.p.) inversely proportional to the product of the numbers of sections: also that the change of the space-factor ratio from 4/3 to 3/4 does not cause much change in X_1 and X_2, unless in the three-section winding. Hence, by aid of this table we can obtain very approximate values of

X_1 and X_2 for other windings, and for windows of other shapes by interpolation.

Numbers of Sections.		Ratios of space-factors q_2/q_1	Square Window $b=b'$			Oblong Window $b'=2b$		
Coil 2 i	Coil 1 $i\mp 1$		X_1	X_2	X_1+X_2	X_1	X_2	X_1+X_2
1	2	3/4	—.33	1.75	1.42	—.41	2.75	2.34
1	2	4/3	—.37	1.92	1.55	—.58	3.03	2.45
3	2	4/3	.76	—.29	·47	1.13	—.41	.72
3	2	3/4	.80	—.32	.48	1.21	—.48	.73
3	4	3/4	—.27	.50	.23	—.38	.75	.37
3	4	4/3	—.29	.53	.24	—.41	.79	.38
5	4	4/3	.36	—.21	.15	.54	—.32	.22
5	4	4/5	.38	—.23	.15	.56	—.35	.21
5	6	6/5	—.19	.27	.08	—.29	.44	.15

[Note that the central section always belongs to coil 2 of i sections, i odd.]

50. There is also magnetic leakage due to the lines in the copper conductors, and in the spaces between them, which is of considerable importance in the case of large, low-pressure transformers.

It is well known that the inductance per unit length of a wire, due to the lines in itself is 1/2, and due to the lines between its surface of radius r and a concentric cylinder of radius r' is $2\log r'/r$. In the case of insulated wire wound in a coil it will be very near the truth to take for r' the radius of the circle equal in area to the total area allowed each wire in the winding, so that if q be the space-factor

$$\frac{\pi r^2}{\pi r'^2}=q,$$

and the inductance of the wire per unit length will be

$$\tfrac{1}{2}+\log\frac{1}{q}.$$

Hence, if l be the mean length of a turn of either coil, their inductances arising from this cause are

$$L'''_1=n_1 l\left\{\tfrac{1}{2}+\log\frac{1}{q_1}\right\},$$

$$L'''_2 = n_2 l\left\{\tfrac{1}{2} + \log\frac{1}{q_2}\right\},$$

and if x'''_1, x'''_2 be the corresponding leakage coefficients

$$x'''_1 = \frac{L'''_1}{n_1^2\sigma} = \frac{l}{n_1\sigma}\left\{\tfrac{1}{2} + \log\frac{1}{q_1}\right\},$$

$$x'''_2 = \frac{L'''_2}{n_2^2\sigma} = \frac{l}{n_2\sigma}\left\{\tfrac{1}{2} + \log\frac{1}{q_2}\right\}.$$

Now it is easy to show by means of relations already given, that

$$\frac{l}{n_1\sigma} = \frac{2wP_2}{\rho c\tau E_1} \text{ and } \frac{l}{n_2\sigma} = \frac{2wP_2}{\rho c\tau E_2}.$$

where P_2=full load (non-inductive) output, c=amp. of current density, ρ=sp. res. of copper; so that we have

$$x'''_1 = \frac{wP_2}{\rho c\tau E_1}\left\{1 + 2\log\frac{1}{q_1}\right\},$$

$$x'''_2 = \frac{wP_2}{\rho c\tau E_2}\left\{1 + 2\log\frac{1}{q_2}\right\}.$$

It will be shown, for similar transformers designed on the same lines, that τ is proportional to $\sqrt{wP_2}$, hence if the e.m.f.s remain fixed, x'''_1 and x'''_2 will increase as the square root of the product of output and frequency increases.

If the conductors be rectangular in section instead of circular, the above expressions for x_1''' and x_2''' will be sufficiently accurate for all practical purposes.

Note.—The connectors from the ends of either coil to the corresponding terminals outside the cases of large transformers ought to include as small an area as possible, since on account of the proximity of the iron of the transformer and of the case, the loops so formed would have considerable inductance, thus increasing the leakage coefficients, especially that of the low pressure coil, and so impairing the regulation on inductive loads.

51. Let us determine the leakage coefficients x_p, x_s, for the transformer designed in Section II. [In this paragraph x_p, x_s, will be the primary and secondary coefficients respectively, while x_2, q_2, etc., will still refer to the coil with the middle section].

The details for this transformer are (see §§ 28 et seq.),

$i=1$, $b=b'$, $\beta=\beta'$, $\beta=1.151b$, $\mu=2250$,

$\rho=1800$, $c=12.9$, $E_1=3111.10^8$, $E_2=311.10^8$.

$P_2=12.5$.K.W., $\tau=6080$, $w=100\pi$, and as the middle coil is the primary one $q_2=q_p=.5$, $q_1=q_s=.7$.

From § 47, *f*, taking the lower signs,

$$x'_1=\frac{2b+\beta}{3\mu\beta}\,\frac{\frac{17}{12}+1}{2}=.000490$$

$$x'_1=\frac{2b+\beta}{3\mu\beta}\,\frac{\frac{7}{12}-1}{2}=-.000084.$$

From § 49, taking from the table the values of X_2 and X_1, $i=1$, $b=b_1^7$, and $q_2/q_1=3/4$, which is sufficiently close to $5/7$, we get

$$x''_2=\frac{(2\beta+\pi b)(2b+\beta)}{4\pi\mu\beta^2}1.75=.00080$$

$$x''_1=-\frac{(2\beta+\pi b)(2b+\beta)}{4\pi\mu\beta^2}.33=-.00015$$

From § 50,

$$x'''_2=x'''_p=\frac{9}{10^7}(1+2\log 2)=.000002,$$

$$x'''_1=x'''_s=\frac{9}{10^6}\left(1+2\log\frac{10}{7}\right)=.000015,$$

which in this case of few sections are relatively negligible.

But $x_p=x'_2+x''_2+x'''_2$, $x_s=x'_1+x''_1+x'''_1$, hence $x_p=.00129$, $x_s=-.00024$, $x_p+x_s=.00105$.

If this transformer had been wound so that the secondary as a single coil occupied the central position, with half of the primary on either side, its leakage coefficients x'_p, x'_s would be

$x'_p=-.00029$, $x'_s=.0014$.

and it is interesting to find what effect this change in the relative positions of the two coils would have on the efficiency for inductive loads.

When we neglect all small terms but the one that depends on the first power of the leakage, we find from §15 that the maximum efficiency

$$\eta=\frac{1}{1+\frac{2}{\text{Cos}\phi}\sqrt{\text{TSin}\delta}+2x_s\tan\phi\text{Sin}\delta}$$

$$=\left\{1-\frac{2}{\text{Cos}\phi}\sqrt{\text{TSin}\delta}\right\}(1-2x_s\tan\phi\text{Sin}\delta)$$

$$=\eta_0(1-2x_s\tan\phi\text{Sin}\delta)\qquad\text{(q.p.)}$$

where $T = \frac{1}{\tau_1} + \frac{1}{\tau_2} = \frac{2}{\tau}$

Hence η is proportional to $1-2x_s\tan\phi\text{Sin}\delta$ and the ratio η/η' of the efficiencies of the same transformer, but differently wound as above, is for loads of the same power factor,

$$\frac{\eta}{\eta'} = \frac{1-2x_s\tan\phi\text{Sin}\delta}{1-2x'_s\tan\phi\text{Sin}\delta}$$
$$= 1-2(x_s - x'_s)\tan\phi\text{Sin}\delta,$$
$$= 1+.00328\tan\phi\text{Sin}\delta,$$

as $x_s = -.00024$, $x'_s = .0014$.

If $\text{Cos}\phi$, the power factor of the load, be .8, $\tan\phi = .75$,

and $\frac{\eta}{\eta'} = 1.0019$ (taking $\delta = 50°$),

and if $\text{Cos}\phi = .6$, $\tan\phi = 4/3$,

and

$$\frac{\eta}{\eta'} = 1.0034.$$

So that when the secondary coil occupies the two outside positions the transformer will have for inductive loads, when $\text{Cos}\phi = .8$, a greater efficiency by .19 per cent., and when $\text{Cos}\phi = .6$ a greater efficiency by .34 per cent. than when the primary occupies the outside positions.

For non-inductive loads the difference in efficiency will be very small, as it then depends on the square of x_s.

52. In § 41 it has been shown how, from the data for any particular design, the dimensions of the carcass and approximate values of the numeric τ and of the efficiency can be quickly obtained.

Selecting from the series in § 41, transformer (c), of which the the details are :—

Capacity 12.5 K.W. at 50 periods,

$2b' = 3b$, $2\beta' = 3\beta$, $\beta = 1.141b$, $\tau = 6910$,

$\mu = 2250$, $c = 12.9$, $\text{Sin}\delta = .766$, $q_p = .5$, $q_s = .7$,

to which we will add $E_p = 2200$ volts $= 3111 \cdot 10^8$, $E_s = 311 \cdot 10^8$. let us determine its leakage coefficients and approximate values of its voltage drop for different kinds of loads if it be wound in five sections, three secondary and two primary.

As the middle and end sections belong to the secondary coil, $q_2=.7$, $q_1=.5$ and from the formulae in § 47, *f.*, taking the upper sign we get

$$x'_2=-\frac{.377}{\mu}=-.000168,$$

$$x'_1=\frac{.909}{\mu}=.000404.$$

From the formulae in § 49,

$$x''_2=\frac{.804}{\mu}X_2,\quad x''_1=\frac{.804}{\mu}X_1;$$

for X_2 and X_1, which are to be for a window in which $b'/b=1.5$, we will take the mean of the values given in the table for windows in which $b'/b=1$ and $b'/b=2$, and as $i=3$, five sections, $q_2/q_1=4/3$, we get

$$X_2=-\frac{.29+.41}{2}=-.35$$

$$X_1=\frac{.76+1.13}{2}=.945$$

hence

$$x''_2=-.000125,\quad x''_1=.000338.$$

From the formulae in § 50,

$$x'''_p=.000002,\quad x'''_s=.000014.$$

Hence, as

$$x_p=x'_1+x''_1+x'''_p,\quad x_s=x'_2+x_2''+x'''_s$$

$$x_p=.000744,\quad x_s=-.000279,$$

$$x_p+x_s=.000465.$$

In Section I., § 23, it was shown that R, the drop per cent., can be expressed in the form

$$R=100\left\{x\mathrm{Sin}\phi+t\mathrm{Cos}\phi+x^2\left(\mathrm{Sin}^2\phi+\frac{\mathrm{Cos}^2\phi}{2}\right)+t^2\left(\mathrm{Cos}^2\phi+\frac{\mathrm{Sin}^2\phi}{2}\right)+xt\mathrm{Sin}\phi\mathrm{Cos}\phi\right\}$$

where $x=y(x_p+x_s)$, $t=y\left(\frac{1}{\tau_1}+\frac{1}{\tau_2}\right)=2\frac{y}{\tau}$.

Now to the first order $y=\theta$ (full load values)

and $\theta=\sqrt{\frac{z\tau\mathrm{Sin}\delta}{2}}$ q.p. (see § 17)

where z ($=1$ in this case) is the chosen ratio of copper to iron losses at full load.

Hence in this case

$$y=\sqrt{\frac{6910\ .\ .766}{2}}=51 \qquad \text{(q.p.)}$$

and $x=51\ .\ .000465=.0237,$

$$t=51\ .\ \frac{2}{6910}=.0148.$$

which, by means of the formula for R give the following approximate values for the regulation.

Power Factor. Cosϕ		Drop per cent. R.
1.0	...	1.53
.9	...	2.43
.8	...	2.68
.6	...	2.86

These figures agree remarkably well with the following (already discussed in Section I.), given by the Westinghouse Co. as the regulation of their 10 K.W. 60 period O.D. transformers, which are also wound in five sections—three primary and two secondary. As regards regulation, the 12.5 K.W. 50 period transformer considered above, and the 10 K.W. 60 period Westinghouse one are nearly equivalent, as wP is nearly the same for both [2π . 625 as against 2π . 600].

REGULATION OF EQUIVALENT WESTINGHOUSE TRANSFORMER.

Power Factor Cosϕ		Drop per cent. —
1.0	...	1.65
.9	...	2.45
.8	...	2.65
.6	...	2.80

53. In order to obtain approximate values for the leakage coefficients of transformers of the core type it will be sufficiently accurate to consider the core as straight, and connecting two large masses of iron.

Let the core be circular in section of radius r having coil 2 lying betwen the cylinders whose radii are r and $r+b_2$ and coil 1,

lying between the cylinders whose radii are $r+b_2$ and $r+b_2+b_1$, and let $r+b_2+b_1=r_0$.

The flux density due to C_1 at all points on the cylinder of radius r_0-z is

$$=\frac{4\pi n_1 C_1}{\lambda'}\frac{z}{b_1}$$

where λ' is the length of the windings parallel to the core, and the flux in the C_1 space between the cylinders of radii r_0-z and $r_0-(z+dz)$ is

$$=\frac{4\pi n_1 C_1}{\lambda'}\frac{z}{b_1}2\pi(r_0-z)dz,$$

and it is looped on that part

$$\frac{n_1 C_1}{b_1}z$$

that lies without it, hence it contributes energy dE where

$$dE=\frac{4\pi^2 n_1^2 C_1^2}{\lambda' b_1^2}(r_0-z)\,z^2 dz.$$

Integrating between $z=0$ and $z=b_1$

$$E=\frac{4\pi^2 n_1^2 C_1^2}{\lambda'}\left\{\frac{r_0 b_1}{3}-\frac{b_1^2}{4}\right\}$$

$$=\frac{4\pi^2 n_1^2 C_1^2}{\lambda'}\left\{\frac{(r+b_2)b_1}{3}+\frac{b_1^2}{12}\right\},$$

as $r_0=r+b_1+b_2$.

The current C_1 also sends through the space occupied by coil 2 a uniform flux

$$=\frac{4\pi n_1 C_1}{\lambda'}\pi\left\{(r+b_2)^2-r^2\right\}$$

which is looped on all of n_1C_1 and therefore contributes energy to the amount

$$\frac{4\pi^2 n_1^2 C_1^2}{\lambda'}\left\{r\,b_2+\frac{b_2^2}{2}\right\},$$

so that the energy of C_1 due to those lines that it produces and that do not traverse the core is

$$=\frac{4\pi^2 n_1^2 C_1^2}{\lambda'}\left\{r\left(\frac{b_1}{3}+b_2\right)+\frac{b_1^2}{12}+\frac{b_1 b_2}{3}+\frac{b_2^2}{2}\right\},$$

but it is also $=\frac{1}{2}L_1 C_1^2$

hence

$$L_1=\frac{8\pi^2 n_1^2}{\lambda'}\left\{r\left(\frac{b_1}{3}+b_2\right)+\frac{b_1^2}{12}+\frac{b_1 b_2}{3}+\frac{b_2^2}{2}\right\}.$$

In a similar manner we find that

$$L_2=\frac{8\pi^2 n_2^2}{\lambda'}\left\{\frac{rb_2}{3}+\frac{b_2^2}{12}\right\}$$

$$M_{12}=M_{21}=\frac{8\pi^2 n_1 n_2}{\lambda'}\left\{\frac{rb_2}{2}+\frac{b_2^2}{6}\right\},$$

but

$$x_1=\frac{1}{n_1\sigma}\left\{\frac{L_1}{n_1}-\frac{M_{21}}{n_2}\right\},$$

$$\therefore x_1=\frac{8\pi^2}{\lambda'\sigma}\left\{\left(\frac{b_1}{3}+\frac{b_2}{2}\right)r+\frac{(b_1+2b_2)^2}{12}\right\}, \text{ and similarly}$$

$$x_2=-\frac{8\pi^2}{\lambda'\sigma}\left\{\frac{rb_2}{6}+\frac{b_2^2}{12}\right\}$$

$$x_1+x_1=\frac{8\pi^2}{\lambda'\sigma}(b_1+b_2)\left\{\frac{r}{3}+\frac{b_1+3b_2}{12}\right\}.$$

From which we see that the leakage coefficient, x_2, of the coil next the core is negative.

The equation giving x_2+x_1 can be written

$$x_1+x_2=\frac{4\pi^2}{3\lambda'\sigma}(b_1+b_2)\ (S_1+S_2) \qquad \text{(I.)}$$

where S_1 and S_2 are the mean radii of the two coils; and if q_1 and q_2 be their space factors, their copper sections per unit length of winding are

b_1q_1 and b_2q_2.

These will be equal or very nearly so, and

let $\quad b_1q_1=b_2q_2=s,$

then $\quad b_1+b_2=2s/Q$

where $Q=\dfrac{2q_1q_2}{q_1+q_2}$, the harmonic mean of q_1 and q_2.

The total copper volume

$$=2\pi\lambda'(S_1q_1b_1+S_2q_2b_2)=2\pi\lambda's(S_1+S_2)=\pi Q\lambda'(b_1+b_2)(S_1+S_2),$$

and $\sigma=4\pi\mu\dfrac{\text{Volume of iron}}{\lambda^2}$

where λ=length of magnetic circuit,

hence

x_1+ [illegible]

and [illegible] copper losses

are [illegible]

$$\frac{\text{Vol. copper}}{\text{Vol. iron}}=z\frac{\text{I}}{\text{K}}$$

where K and I are these losses per cm.[3]

$$\therefore \quad x_1+x_2=\frac{\lambda^2}{3\mu Q\lambda'^2}\ z\frac{\text{I}}{\text{K}} \qquad \text{(III.)}$$

a form very suitable for the determination of x_1+x_2 for core transformers.

For example, if $z=1$, $\text{I}=10^5$, $\text{K}=15.10^4$, $q_1=.5$, $q_2=.7$, $\text{Q}=.583$ as before, x_1+x_2 for any core transformer designed on these data is given by

$$x_1+x_2=\frac{\lambda^2}{3\mu\lambda'^2}1.14.$$

For a core transformer of the H type, simply wound, in which the rectangular opening in the stampings is 10.2×25.2 cm., and the width of the surrounding iron strip 8.9 cm. (See § 57)

$\lambda'=2\times25.2=50.4$ cm.

$\lambda=106.4$ cm.

and if $\mu=2250$,

$x_1+x_2=.00075$.

54. If a core transformer be wound with $2i$ layers, i each of primary and secondary arranged alternately, and if D be the total depth of the windings, it can be shown that

$$x_1+x_2=\frac{4\pi^2\text{D}}{3\lambda'\sigma i^3}\times\text{ sum of the mean radii of all the layers,}$$

$$=\frac{8\pi^2\text{D}}{3\lambda'\sigma i^2}\times\text{ mean of the mean radii of all the layers,}$$

which by exactly similar reasoning to that in § 53 can be put into either of the forms,

$$x_1+x_2=\frac{1}{i^2}\,\frac{\lambda^2}{3\mu Q\lambda'^2}\,\frac{\text{volume of copper}}{\text{volume of iron}}.$$

$$\text{or } x_1+x_2=\frac{1}{i^2}\,\frac{\lambda^2}{3\mu\lambda'^2}\,\frac{z\text{I}}{\text{QK}}.$$

If there be i layers of one coil and $i+1$ of the other, then we may take

$$x_1+x_2=\frac{1}{i(i+1)}\,\frac{\lambda^2}{3\mu\lambda'^2}\,\frac{z\text{I}}{\text{QK}}.$$

This result and those in § 53 will be suffi ntly a urate for all practical purposes when the coils are rectan lan.

THE TRANSFORMER NUMERICS.

55. The numeric τ $(=\tau_1=\tau_2$ (q.p.)) for transformers of any given type can be expressed in terms of the full-load output, periodicity, and the magnetic and electric qualities of the iron and copper.

Let us consider the case of transformers of the shell type similar to the one designed in Section II., with square windows $(2b, 2b)$, and iron tongue of square cross section $(2\beta, 2\beta)$.

From § 33

$$\tau = A\frac{\mu w}{\rho}\frac{b^2\beta^2}{(b+\beta)(2b+\beta)} \qquad \text{(I.)}$$

where A is a constant depending on the iron and copper space factors.

From the solution, as in § 32 of the equation

$$\frac{2QKb^2(b+\beta)}{pI\beta^2(2b+\beta)}=z$$

which expresses the relation between the iron and copper losses at full load, we get

$$\beta = Bb \qquad \text{(II.)}$$

in which B will be a constant, if, for all transformers of the series

$$\frac{pIz}{QK}$$

be constant.

We may consider p the iron space factor as fixed, and, provided the primary and secondary pressures remain the same, Q, the harmonic mean of the copper space factors, also as fixed; and the above expression will be constant if z, the ratio of the copper to the iron losses at full load, be the same for all transformers of the series as well as the ratio K/I of copper to iron loss per cm^3 at full load, both however, diminishing slightly in the same proportion as the capacity increases; or

$$z=\text{Const.}\ K=K_0(1-mP_2)\ I=I_0(1-mP_2). \qquad \text{(III.)}$$

where m is a small fraction.

Another way in which Iz/K would be constant, and one more in accordance with the practice of some manufacturers, would be for K and Iz each to be constant, I diminishing as the capacity increased, [illegible] same ratio; or

$$K = \text{Const.},\ I = \frac{I_0}{1+nP_2},\quad z = 1+nP_2. \quad \text{(IV.)}$$

where n is a small fraction.

Again we have the full load output

$$P_2 = \tfrac{1}{2} w n_2 C_2 F \text{ (q.p.)}$$

for a non-inductive load on which the transformer would be rated, but

$$n_2 C_2 = 2Qb^2 c = 2Qb^2 \sqrt{\frac{2K}{\rho}}.$$

and

$$F = 4p\beta^2\gamma = 4p\beta^2\sqrt{\frac{8\pi\mu I}{w \operatorname{Sin}\delta}}.$$

hence

$$P_2 = Db^2\beta^2\sqrt{\frac{\mu w}{\rho \operatorname{Sin}\delta} KI}$$

where D is a constant.

Substituting in equation I. for b and β, their values determined from II. and V., we get

$$\tau = M\sqrt[4]{\frac{\mu^3 w^3 \operatorname{Sin}\delta}{\rho^3}\frac{P_2^2}{KI}}$$

where M is a constant.

Now I find for the same sample of iron that

$$\frac{\mu^3 w \operatorname{Sin}\delta}{I}$$

is very nearly constant when w is constant over the range of flux densities, or of Is, commonly used in transformers, and that it increases slightly as w diminishes.

Taking it as constant, we get

$$\tau = N\sqrt[4]{K}\sqrt{wP_2}$$

Hence if τ for a transformer of a given type be known, the equation

$$\frac{\tau^2}{wP_2} = \text{Const.},$$

will enable us to obtain fairly approximate values of τ for other transformers of the same type that differ in capacity and periodicity.

It is worth noting that equation V. above shows that, for equal heating or equal iron and copper losses per unit volume, the out-

put of a transformer is proportional to $\sqrt{\frac{\mu w}{\text{Sin}\delta}}$.

This is not proportional to the square root of w or of the frequency as, when w increases, μ for the same flux density will diminish and Sinδ will increase.

Most Efficient Shapes of Transformers.

56. It has been shown (§ 21) that when consideration of leakage is neglected, the measure of excellence of a transformer is

$$\frac{\tau}{\text{Sin}\delta};$$

hence the most efficient transformer of a given type and capacity and made of similar iron will be that one for which τ is a maximum.

If a, α be the total cross sections (insulation, etc., included) of the copper and iron circuits respectively, and l, λ their mean lengths, then

$$g\frac{a\alpha}{l\lambda}=\tau,$$

$$\frac{al}{\alpha\lambda}=z\frac{p\text{I}}{\text{Q}\kappa}=z',$$

where g and z' are constants.

Hence, as

$$\tau z'=g\frac{a^2}{\lambda^2},\quad \frac{\tau}{z'}=g\frac{\alpha^2}{l^2}$$

for τ to be a maximum,

$$\frac{\lambda}{a} \text{ and } \frac{l}{\alpha}$$

must both be minima, and as the output

$$\text{P}_2=ha\alpha,$$

where h is a constant, as the flux and current densities will be fixed, the problem resolves itself into finding values for the dimensions of the carcass that will make

$\frac{\lambda}{a}$ and $\frac{l}{\alpha}$ both minima when $a\alpha$ is constant.

Specifying the dimensions of a shell transformer in the usual way (window $=2b$, $2b'$, tongue $=2\beta$, $2\beta'$),

$$a=4bb',\quad l=4(\beta+\beta'+2b),$$

$$\alpha=4\beta\beta',\quad \lambda=4(b+b'+\beta).$$

and proceeding by the method of indeterminate multipliers (A, B, C),

$$\mathrm{A}d\left(\frac{\lambda}{a}\right)+\mathrm{B}d\left(\frac{l}{a}\right)+\mathrm{C}d(a\alpha)=0$$

in which the coefficients of db, db', $d\beta$, and $d\beta'$ being equated to zero give us,

$$\frac{b'+\beta}{b^2b'}\mathrm{A}-\frac{2}{\beta\beta'}\mathrm{B}+b'\beta\beta'\mathrm{C}=0$$

$$\frac{b+\beta}{bb'^2}\mathrm{A}\qquad\qquad+b\beta\beta'\mathrm{C}=0$$

$$-\frac{1}{bb'}\mathrm{A}+\frac{\beta'+2b}{\beta^2\beta'}\mathrm{B}+bb'\beta'\mathrm{C}=0$$

$$\frac{\beta+2b}{\beta\beta'^2}\mathrm{B}+bb'\beta\mathrm{C}=0.$$

Eliminating A, B, and C from any two sets of three of these equations we get the two relations

$$\left.\begin{array}{l}\beta(3b-b')=2b(b'-2b)\\ \beta(\beta'-2\beta)=b(3\beta-\beta')\end{array}\right\}\qquad\text{(I.)}$$

which show that $b'>2b$ and $<3b$
and $\qquad\beta'>2\beta$ and $<3\beta$.

Let $b'=\xi b,\quad \beta'=\eta\beta,\quad \beta=ub,$
and equations I. can be put in the forms

$$\left.\begin{array}{l}u=2\dfrac{\xi-2}{3-\xi}=\dfrac{3-\eta}{\eta-2}\\ \text{or } \xi=\dfrac{3u+4}{u+2},\quad \eta=\dfrac{2u+3}{u+1}\end{array}\right\}\qquad\text{(II.)}$$

by means of which the equation of the losses

$$\frac{al}{a\lambda}=z\frac{p\mathrm{I}}{\mathrm{QK}}$$

becomes

$$\frac{(3u+4)(3u^2+6u+2)}{u^2(2u+3)(u^2+6u+6)}=z\frac{p\mathrm{I}}{\mathrm{QK}},\qquad\text{(III.)}$$

from which u (the one positive root) can be determined by trial when $zp\mathrm{I}/\mathrm{QK}$ is known. ξ and η are found from u by equations II., and so the shapes of window and tongue and their relative sizes are determined.

The relation $\frac{1}{2}\,wn_2\mathrm{C}_2\mathrm{F}=\mathrm{P}_2$
can now be reduced to

$$b^4u^2\xi\eta=\frac{\mathrm{P}_2}{4p\mathrm{Q}c_2\gamma w}\qquad\text{(IV.)}$$

from which b, and hence the transformer, is determined.

The equation for τ can be put in the form

$$\tau = \frac{\pi\mu P_2}{2\rho c_2\gamma}\,\frac{1}{(\beta+\beta^1+2b)\,(b+b^1+\beta)}$$

$$\text{or } \tau = \frac{\pi\mu P_2}{2\rho c_2\gamma b^2}\,\frac{1}{(1+\xi+u)\,(2+u+\eta u)} \qquad \text{(V.)}$$

by means of which it can be quickly calculated, and it will be found that the result is a true maximum.

For example, assuming the same data for design as are adopted in §§ 41 and 52,

$$z\frac{pI}{QK} = 1.029,$$

and equation III. gives

$$u = 1.1,$$

hence by means of II. we find that $b' = 2.35b$, $\beta' = 2.48\beta$, which with $\beta = 1.1b$, give the most efficient shape for a shell transformer in which $zpI/QK = 1.029$.

If $P_2 = 12.5$ K.W., the same capacity as that of the transformers in § 41, equation IV gives

$$b = 4.55,$$

and equation V.,

$$\tau = 7300.$$

The losses being al QK and $a\lambda pI$, we find that each is equal to 181 watts, so that the efficiency at full load is 97.2 per cent.

This maximum efficiency transformer will not have such good regulation on inductive loads as others less efficient, but with relatively wider windows. A compromise between efficiency and regulation can always be made suitable to the nature of the work the transformer is intended for.

For the above transformer, if wound in five sections, $x_1 + x_2 =$ .00075; and the regulation would be, for a non-inductive load, 1.55 per cent., and for an inductive load of .8 power factor, 3.7 per cent. These figures can be compared with those in § 52.

57. A core transformer of the H type, in which the magnetic circuit is rectangular (2β, $2\beta'$) in section and the coils rectangular in plan, is exactly the same in geometrical shape as a shell transformer, but the copper and iron circuits of the former occupy the places of the iron and copper circuits of the latter.

Let $2b$, $2b'$ be the dimensions of the rectangular windows, or winding apertures in the laminae, the coils being wound round the $2b'$ dimension, 2β the width of the iron strip, and $2\beta'$ the dimension of the core measured perpendicular to the laminae, then

$$a = 4bb', \quad l = 4(\beta + \beta' + b),$$
$$\alpha = 4\beta\beta', \quad \lambda = 4(b + b' + 2\beta).$$

and we find as in § 56, or by simply interchanging β and b, β' and b' in I., § 56, that for maximum τ, that is maximum efficiency

$$b(3\beta - \beta') = 2\beta(\beta' - 2\beta),$$
$$b(b' - 2b) = \beta(3b - b').$$

If $b' = \xi b$, $\beta' = \eta\beta$, and $\beta = ub$ as before,

$$u = \frac{\xi - 2}{3 - \xi} = \frac{1}{2}\frac{3 - \eta}{\eta - 2},$$

$$\xi = \frac{3u + 2}{u + 1}, \quad \eta = \frac{4u + 3}{2u + 1}; \qquad \text{(II.)}$$

and the equation of the losses is

$$\frac{(3u + 2)(6u^2 + 6u + 1)}{u^2(4u + 3)(2u^2 + 6u + 3)} = z\frac{pI}{QK}$$

provided the coils are wound in a number of alternate layers so that the mean lengths of the primary and secondary turns are equal.

From this equation u can be found, and thence by II., ξ and η.

The equation of the output (see § 56, IV.)

$$b^4 u^2 \xi\eta = \frac{P_2}{4pQc_2\gamma w}$$

gives b, which with u, ξ and η, determine the transformer.

In this case

$$\tau = \frac{\pi\mu P_2}{2\rho c_2 \gamma b^2} \frac{1}{(1 + \xi + 2u)\,(1 + u + u\eta)}$$

For example, if

$$z\frac{pI}{QK} = 1.029,$$

$P_2 = 12.5$ K.W. as before,

then $u = .876$, $\xi = 2.47$, $\eta = 2.36$, $b = 5.1$,

and $\tau = 7320$, just the least thing better than the maximum efficiency transformer of the shell type.

If $zpI/QK=1$, max. τ would be the same for both types, and if $zpI/QK<1$, the shell type would be the better.

Magnetic leakage is in general less, and good regulation more easy to attain in core transformers than in shell transformers. To enable a comparison to be made with the shell transformer in the last paragraph, we will determine the sum of the leakage coefficients and the regulation for different kinds of load of the core transformer considered above, supposing it to be wound (*a*) in three layers, one primary and two secondary or *vice versa* ; (*b*) in five layers, two primary and three secondary or *vice versa.*

From § 54,

$$x_1+x_2=\frac{1}{ij}\cdot\frac{\lambda^2}{3\mu\lambda'^2}\cdot\frac{zI}{QK},$$

and $\lambda=4(b+b'+2\beta)$, $\lambda'=4b'$, so that, using the same values for the constants as before, we find,

for (*a*) $x_1+x_2=.000381$,

(*b*) $x_1+x_2=.000127$,

from which, proceeding as in § 52, we find for the regulation

Power Factor.	Drop per cent.	
	(*a*) Three layers.	(*b*) Five layers.
1.0	1.49	1.47
.8	2.43	1.58
.6	2.55	1.43

58. It is obvious that in core transformers of the ring type in which the winding is continuous all round, the maximum efficiency shape will, other things being equal, be that in which the magnetic circuit is shortest, that is when the opening in the laminae is filled with the copper circuits. The ring type is not suitable for practical construction, but a near approach to it is the Burnand transformer,* in which the magnetic circuit is formed of square laminae from which a symmetrically placed inner square has been removed to give the winding space. Each side of the square is built and wound separately with triangular

* See "Electrician," Sept. 19, 1902.

shaped windings, and the four sides jointed together to fo
completed transformer.

Let us determine the proportions of such a transformer
τ, and hence the efficiency, shall be a maximum.

Let $2b$, $2b$, be the square opening in the laminae, 2β,
cross section of the magnetic circuit, 2β being measured
planes of the laminae, then,

$$a = 4b^2, \quad l = 4(\beta + \beta' + \tfrac{2}{3}b)$$

$$\alpha = 4\beta\beta', \quad \lambda = 8(b + \beta)$$

Proceeding as in § 56 we find, in order that

$\frac{\lambda}{a}$ and $\frac{l}{\alpha}$ shall be minima

when $a\alpha$ is constant,

that $\quad 2\beta(\beta' - 2\beta) = b(3\beta - \beta')$

and if $\beta' = \eta\beta$, $\beta = ub$ as before,

$$u = \tfrac{1}{2}\frac{3-\eta}{\eta - 2}, \quad \eta = \frac{4u+3}{2u+1},$$

and the equation of the losses

$$\frac{al}{\alpha\lambda} = z\frac{pI}{QK}$$

becomes

$$\frac{18u^2 + 16u + 2}{6u^2(4u^2 + 7u + 3)} = z\frac{pI}{QK},$$

from which, for any given values of z, p, Q, I and K, u
found and hence η.

The equation of the output,

$$b^4u^2\eta = \frac{P_2}{4pQc_2\gamma w},$$

gives b, which with u and η, determine the transformer.

For example, if we take as before

$$z\frac{pI}{QK} = 1.029, \quad P_2 = 12.5 \text{ K.W.}$$

we find

$$u = .577, \quad \eta = 2.464,$$

$$b = 7.8, \quad \beta = 4.5, \quad \beta' = 11.09,$$

and the value of τ is 7680, which is considerably larger and
better than for either of the two preceding types.

Iron loss = copper loss = 176.7 watts.

Efficiency = 97.26 per cent.

These transformers are wound in five or seven layers and their regulation is of a very high order. The formula in § 54 would only enable us to obtain a very rough approximation to $x_1 + x_2$ for this type.

General Solution of the Transformer Problem by a Vector Method.

Explanatory.

59. (*a*) If a be any vector representing e.m.f., current, or flux, on the plane alternate current diagram (Fig. 2) and if we understand by

$$\iota a$$

the vector got by rotating a through a right angle in the positive direction, and hence if we understand by

$$(\mathrm{Cos}\theta + \iota\mathrm{Sin}\theta)a \text{ or } e^{\iota\theta}a$$

the vector got by rotating a through the angle θ in the positive direction, then it is well-known that operators such as $e^{\iota\theta}$ can be manipulated as ordinary algebraic symbols, and that ι can be treated as if it were the algebraic imaginary $\sqrt{-1}$.*

(*b*) If a_1, a_2, a_3 etc., be numerical multipliers, then the vector

$$\left\{ a_1e^{\iota\theta_1} + a_2e^{\iota\theta_2} + a_3e^{\iota\theta_2} + \quad \right\} a,$$

or the resultant or sum of the vectors

$$a_1e^{\iota\theta_1}a, \; a_2e^{\iota\theta_2}a, \; a_3e^{\iota\theta_3}a, \text{ etc.}$$

is

$$= \{\Sigma a\mathrm{Cos}\theta + \iota\Sigma a\mathrm{Sin}\theta\}a$$

$$= \mathrm{A}(\mathrm{Cos}\psi + \iota\mathrm{Sin}\psi)a = \mathrm{A}e^{\iota\psi}a$$

where

$$\mathrm{A}^2 = (\Sigma a\mathrm{Cos}\theta)^2 + (\Sigma a\mathrm{Sin}\theta)^2$$

$$= \Sigma a^2 + 2\Sigma a_1a_2\mathrm{Cos}(\theta_1 - \theta_2)$$

and

$$\tan\psi = \frac{\Sigma a\mathrm{Sin}\theta}{\Sigma a\mathrm{Cos}\theta},$$

hence the operator

$$a_1e^{\iota\theta_1} + a_2e^{\iota\theta_2} + a_3e^{\iota\theta_3} + \text{etc.} = \mathrm{A}e^{\iota\psi}$$

where A and ψ are given by the above equations.

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*Lyle. *Alternate Current Problems.* "Electrician," 41, pp. 816-818; 42, pp. 72-74 and 148-151, 1898.

(*c*) If a represent the harmonically varying quantity $n\mathrm{Cos}wt$ then since

$$\frac{d}{dt}(n\mathrm{Cos}wt)=wn\mathrm{Cos}\left(wt+\frac{\pi}{2}\right)$$

$we^{\iota\frac{\pi}{2}}a$ or $w\iota a$ will represent $\frac{d}{dt}(n\mathrm{Cos}wt)$, and we may write

$$\frac{d}{dt}a=we^{\iota\frac{\pi}{2}}a=w\iota a.$$

60. If $\sigma/4\pi$ be the permeance of the magnetic circuit, closed or open, and limited in section by the iron core where the latter exists; and if δ be the angle of magnetic lag of the iron, then as the flux density remains very nearly constant throughout the range of operation of a transformer, we may without much error consider σ and δ as constants.

The total number N_1 of magnetic lines looped on the n_1 turns of the primary coil is the sum of three sets, namely,

1. Those traversing the iron core, produced by the magnetising ampere turns $\overline{n_1C_1+n_2C_2}$, and behind them in phase by the angle δ.

Hence these

$$=\sigma e^{-\iota\delta}\overline{(n_1C_1+n_2C_2)}$$

2. Those produced by $\overline{C}_1$ and in phase with it that miss the iron core.

Let these

$$=x_{11}\sigma n_1\overline{C}_1.$$

3. Those produced by $\overline{C}_2$ and in phase with it that miss the iron core.

Let these

$$=x_{21}\sigma n_2\overline{C}_2.$$

Hence

$$N_1=n_1\sigma(e^{-\iota\delta}+x_{11})\overline{C}_1+n_2\sigma(e^{-\iota\delta}+x_{21})\overline{C}_2$$

similarly

$$N_2=n_1\sigma(e^{-\iota\delta}+x_{12})\overline{C}_1+n_2\sigma(e^{-\iota\delta}+x_{22})\overline{C}_2$$

where x_{22} and x_{12} have similar significations with regard to the secondary coil that x_{11} and x_{21} have with regard to the primary.

We thus have four leakage coefficients and it will be noticed that they are connected with the two coefficients x_1 and x_2 hitherto used by the equations

$$x_1 = x_{11} - x_{21}$$
$$x_2 = x_{22} - x_{12} \text{ (see § 43).}$$

61. The equations of motion are

$$\overline{\mathrm{E}}_1 = r_1\overline{\mathrm{C}}_1 + n_1\frac{d}{dt}\overline{\mathrm{N}}_1 = r_1\overline{\mathrm{C}}_1 + wn_1 e^{\iota\frac{\pi}{2}}\overline{\mathrm{N}}_1 \qquad \text{(I.)}$$

$$\overline{\mathrm{E}}_2 = -r_2\overline{\mathrm{C}}_2 - n_2\frac{d}{dt}\overline{\mathrm{N}}_2 = -r_2\overline{\mathrm{C}}_2 - wn_2 e^{\iota\frac{\pi}{2}}\overline{\mathrm{N}}_2 \qquad \text{(II.)}$$

where $\overline{\mathrm{E}}_1$, $\overline{\mathrm{E}}_2$, are the terminal e.m.f's, and r_1, r_2, the internal resistances of the coils.

If R be the external resistance or its equivalent in the secondary circuit, and $\mathrm{Cos}\phi$ the power-factor of the load,

$$\overline{\mathrm{E}}_2\mathrm{Cos}\phi = \mathrm{R}e^{\iota\phi}\overline{\mathrm{C}}_2 \qquad \text{(III.)}$$

Eliminating E_2 between equations (II.) and (III.) and putting

$$\frac{wn_1^2\sigma}{r_1} = \tau_1 \quad \frac{wn_2^2\sigma}{r_2} = \tau_2$$

$$\frac{wn_2^2\sigma}{\mathrm{R}}\mathrm{Cos}\phi = \theta$$

[Note that the θ here is the same as the $\theta\mathrm{Cos}\phi$ in the early part of this paper.]

we get

$$(1 + x_{12}e^{\iota\delta})n_1\overline{\mathrm{C}}_1 = -\left(1 + x_{22}e^{\iota\delta} + \frac{1}{\tau_2}e^{-\iota(\frac{\pi}{2}-\delta)} + \frac{1}{\theta}e^{-\iota(\frac{\pi}{2}-\delta-\phi)}\right)n_2\mathrm{C}_2 \qquad \text{(IV.)}$$

from which by § 59, *b*, we find that

$$\frac{n_1\mathrm{C}_1}{\Delta} = \frac{n_2\mathrm{C}_2}{\theta\mathrm{X}_{12}} \qquad \text{(V.)}$$

where

$$\Delta^2 = \theta^2\left(1 + 2x_{22}\mathrm{Cos}\delta + 2\frac{\mathrm{Sin}\delta}{\tau_2} + x_{22}^2 + \frac{1}{\tau_2^2}\right) + 2\theta\left\{\mathrm{Sin}(\delta+\phi) + x_{22}\mathrm{Sin}\phi + \frac{\mathrm{Cos}\phi}{\tau_2}\right\} + 1,$$

$$\mathrm{X}_{12}^2 = 1 + 2x_{12}\mathrm{Cos}\delta + x_{12}^2;$$

and that

$$\tan\beta = \frac{\text{Cos}(\delta+\phi)+x_{12}\text{Cos}\phi+\theta\left\{(x_{12}-x_{22})\text{Sin}\delta+\frac{\text{Cos}\delta}{\tau_2}+\frac{x_{12}}{\tau_2}\right\}}{\text{Sin}(\delta+\phi)+x_{12}\text{Sin}\phi+\theta\left\{1+(x_{12}+x_{22})\text{Cos}\delta+\frac{\text{Sin}\delta}{\tau_2}+x_{12}x_{22}\right\}}$$

where $\pi-\beta$ is the angle that $\overline{C}_2$ is behind $\overline{C}_1$ in phase.

62. Eliminating $\overline{C}_2$ from equations (I.) and (IV.) and puttir

$$x_{11}-x_{21}+x_{22}-x_{12}=X,$$

$$\frac{1}{\tau_1}+\frac{1}{\tau_2}=T,$$

$$x_{11}x_{22}-x_{12}x_{21}-\frac{1}{\tau_1\tau_2}=m,$$

$$\frac{x_{11}}{\tau_2}+\frac{x_{22}}{\tau_1}=n,$$

we get

$$\frac{n_1\overline{E}_1}{r_1\tau_1}=\frac{e^{\iota(\phi-\delta)}+x_{11}e^{\iota\phi}+\frac{1}{\tau_1}e^{-\iota(\frac{\pi}{2}-\phi)}}{e^{-\iota(\frac{\pi}{2}-\phi)}+\theta\left\{e^{-\iota\delta}+x_{22}+\frac{1}{\tau_2}e^{-\iota\frac{\pi}{2}}\right\}}n_1\overline{C}_1$$

$$+\frac{\theta\left\{Xe^{\iota(\frac{\pi}{2}-\delta)}+Te^{-\iota\delta}+me^{\iota\frac{\pi}{2}}+n\right\}}{e^{-\iota(\frac{\pi}{2}-\phi)}+\theta\left\{e^{-\iota\delta}+x_{22}+\frac{1}{\tau_2}e^{-\iota\frac{\pi}{2}}\right\}}n_1\overline{C}_1$$

from which by § 59, *b*, we find that

$$\frac{n_1C_1}{\Delta}=\frac{n_1E_1}{r_1\tau_1}\cdot\frac{1}{D} \qquad \text{(VI.)}$$

where

$$D^2=1+2x_{11}\text{Cos}\delta+2\frac{\text{Sin}\delta}{\tau_1}+x_{11}^2+\frac{1}{\tau_1^2}+2\theta\left\{X\text{Sin}\phi+T\text{Cos}\phi\right.$$
$$+\left(x_{11}X+\frac{T}{\tau_1}\right)\text{Sin}(\delta+\phi)+\left(x_{11}T-\frac{X}{\tau_1}\right)\text{Cos}(\delta+\phi)+n\text{Cos}(\delta-\cdot$$
$$\left.-m\text{Sin}(\delta-\phi)+\left(x_{11}m+\frac{n}{\tau_1}\right)\text{Sin}\phi+\left(x_{11}n-\frac{m}{\tau_1}\right)\text{Cos}\phi\right\}$$
$$+\theta^2\{X^2+T^2+m^2+n^2\}$$

also, if a be the angle that $\overline{C}_1$ is behind $\overline{E}_1$ in phase, so that Co
is the power factor of the transformer,

$$\mathrm{D} \triangle \operatorname{Cos}\alpha = \operatorname{Sin}\delta + \frac{1}{\tau_1} + \theta\Big\{ \operatorname{Cos}\phi + \frac{2\operatorname{Sin}(\delta+\phi)}{\tau_1} + (x_{12}+x_{21})\operatorname{Cos}(\delta+\phi)$$

$$+2\Big(x_{22}\operatorname{Sin}\phi + \frac{\operatorname{Cos}\phi}{\tau_2}\Big)\operatorname{Sin}\delta + 2\frac{x_{22}}{\tau_1}\operatorname{Sin}\phi + \Big(x_{12}x_{21} + \frac{2}{\tau_1\tau_2}\Big)\operatorname{Cos}\phi\Big\}$$

$$+\theta^2\Big\{\mathrm{T} + \Big[(x_{22}-x_{12})\,(x_{22}-x_{21}) + \frac{2}{\tau_1\tau_2} + \frac{1}{\tau_2^{\,2}}\Big]\operatorname{Sin}\delta +$$

$$\Big[\frac{2x_{22}}{\tau_1} + \frac{x_{21}+x_{12}}{\tau_2}\Big]\operatorname{Cos}\delta + \frac{x_{22}^{\,2}}{\tau_1} + \frac{1}{\tau_1\tau_2^{\,2}} + \frac{x_{12}x_{21}}{\tau_2}\Big\} =$$

$$\mathrm{Q} = q_0 + q_1\theta + q_2\theta^2 \text{(say)}. \qquad \text{(VII.)}$$

The power P_1 taken in by the transformer on the primary side being

$$= \tfrac{1}{2}E_1C_1\operatorname{Cos}\alpha$$

we find

$$\mathrm{P} = \frac{1}{2}\frac{E_1^2}{r_1\tau_1}\ \frac{\mathrm{Q}}{\mathrm{D}^2}. \qquad \text{(VIII.)}$$

63. From equations (V.) and (VI.) we get

$$\frac{n_2C_2}{\theta X_{12}} = \frac{n_1E_1}{r_1\tau_1}\ \frac{1}{\mathrm{D}} \qquad \text{(IX.)}$$

and as $E_2\operatorname{Cos}\phi = \mathrm{R}C_2$ and $\theta = \dfrac{wn_2^{\,2}\sigma}{\mathrm{R}}\operatorname{Cos}\phi$,

we find that

$$E_2 = \frac{n_2}{n_1}\ \frac{X_{12}}{\mathrm{D}}E_1. \qquad \text{(X.)}$$

As the output $P_2 = \frac{1}{2}E_2C_2\operatorname{Cos}\phi$ we find that, substituting for E_2 and C_2, that

$$P_2 = \frac{1}{2}\frac{E_1^{\,2}}{r_1\tau_1}\ \frac{X_{12}^{\,2}}{\mathrm{D}^2}\theta\operatorname{Cos}\phi. \qquad \text{(XI.)}$$

64. Equation (IV.) of § 61 can be written in the form,

$$(1+x_{12}e^{\iota\delta})\,\overline{(n_1C_1+n_2C_2)} = -\Big\{(x_{22}-x_{12})e^{\iota\delta} + \frac{1}{\tau_2}e^{-\iota\left(\frac{\pi}{2}-\delta\right)} + \frac{1}{\theta}e^{-\iota\left(\frac{\pi}{2}-\delta-\phi\right)}\Big\}n_2\overline{C}_2$$

but $\overline{n_1C_1+n_2C_2} = \overline{F/\sigma}$,
and, by § 59, *b*, we find that

$$\frac{F/\sigma}{\mathrm{M}} = \frac{n_2C_2}{\theta X_{12}} \qquad \text{(XII.)}$$

where

$$M^2 = 1 + 2\theta\left\{(x_{22}-x_{12})\text{Sin}\phi + \frac{1}{\tau_2}\text{Cos}\phi\right\} + \theta^2\left\{(x_{22}-x_{12})^2 + \frac{1}{\tau_2^2}\right\}$$

and $X^2_{12} = 1 + 2x_{12}\text{Cos}\delta + x_{12}^2$ (as before).

Combining equations (XII.) and (IX.), we have

$$\frac{F}{\sigma M} = \frac{n_1 E_1}{r_1\tau_1}\frac{1}{D} \qquad \text{(XIII.)}$$

and as the iron loss (see § 14),

$$H_8 = \tfrac{1}{2}w\frac{F^2}{\sigma}\text{Sin}\delta,$$

we find by means of equation (XIII.), that

$$H_8 = \tfrac{1}{2}\frac{E_1^2}{r_1\tau_1}\;\frac{M^2}{D^2}\text{Sin}\delta. \qquad \text{(XIV.)}$$

65. The primary copper loss H_1 being

$$= \tfrac{1}{2}r_1C_1^2$$

we find by equation (VI.), § 62, that

$$H_1 = \tfrac{1}{2}\frac{E_1^2}{r_1\tau_1^2}\;\frac{\Delta^2}{D^2},$$

and the secondary copper loss H_2 being

$$= \tfrac{1}{2}r_2C_2^2;$$

also we find by equation (IX.), § 63, that

$$H_2 = \tfrac{1}{2}\frac{E_1^2}{r\tau_1\tau_2}\;\frac{\theta^2 X_{12}^2}{D^2}.$$

66. The efficiency

$$\eta = \frac{P_2}{P_1} = \frac{X_{12}^2\theta\text{Cos}\phi}{Q}$$

$$= X_{12}^2\text{Cos}\phi\frac{\theta}{q_0+q_1\theta+q_2\theta^2} \qquad \text{(see §§ 62, 63),}$$

is a maximum when

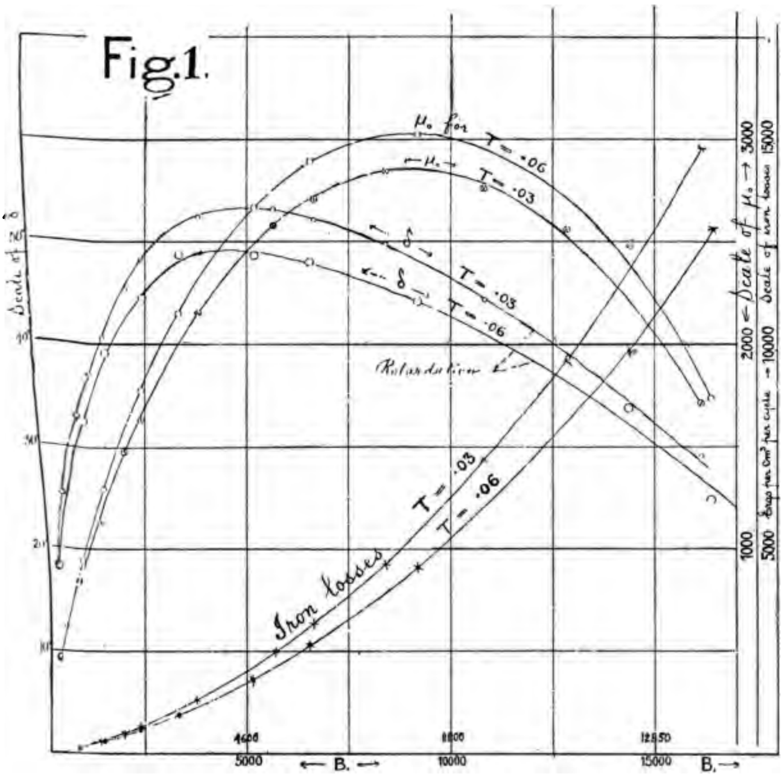
$$\theta^2 = \frac{q_0}{q_2} \quad \text{(see § 15),}$$

and its maximum value is

$$\frac{X_{12}^2\text{Cos}\phi}{q_1+2\sqrt{q_0q_2}}.$$

67. Thus, without making any assumptions as regards leakag
all the important variables in the general theory of the trar

Fig.1.



μ_o for
T = ·06
← μ_o →
T = ·03
δ
T = ·03
δ
T = ·06
Retardation
Iron losses
T = ·03
T = ·06
Scale of δ
2000 ← Scale of μ_o → 3000
1000
5000 Ergs per Cm³ per cycle → 10000 Scale of iron losses 15000
4600
8800
12850
5000
← B. →
10000
15000
B. →

Fig. 2.

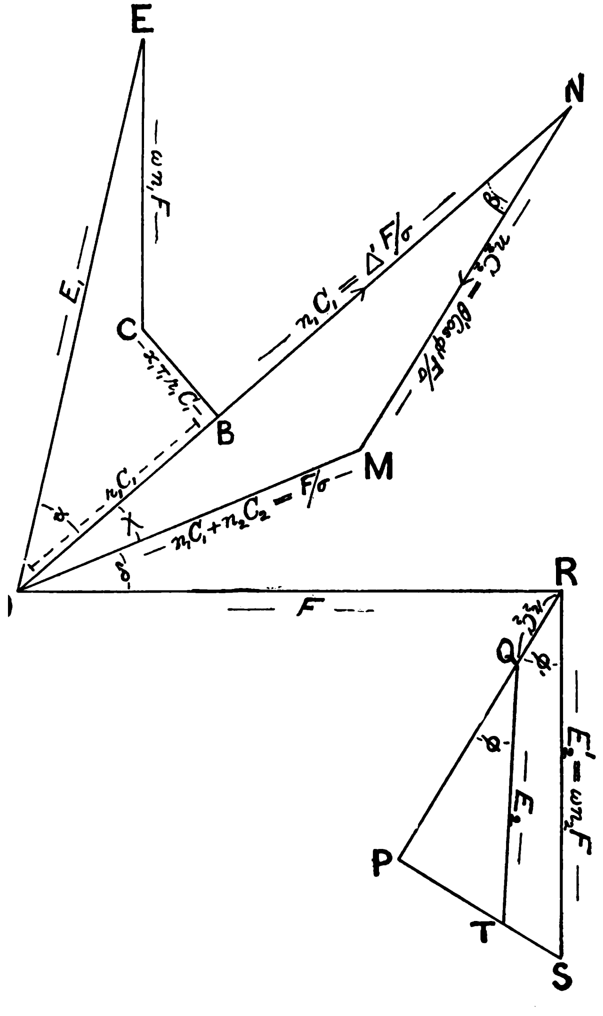


Fig. 3.

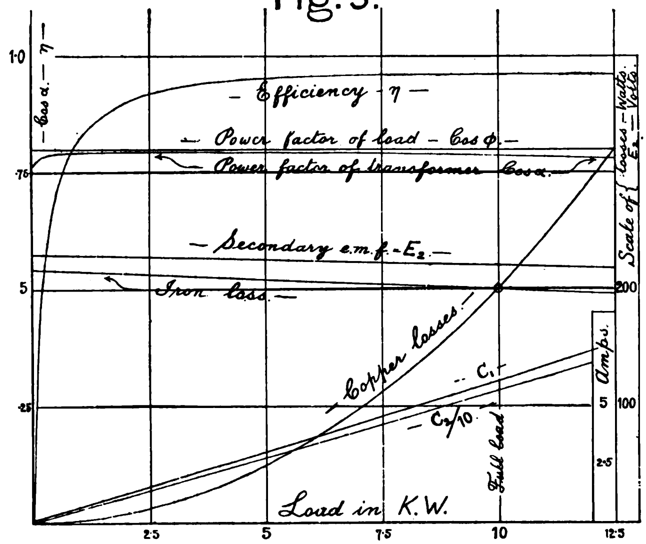

– Efficiency – η –
– Power factor of load – Cos φ –
Power factor of transformer Cos α
– Secondary e.m.f. – E_2 –
Iron loss –
Copper losses –
– C_1 –
– $C_2/10$ –
Full load
Load in K.W.
Amps.
Scale of { losses – Watts. / E_2 – Volts.
– Cos α – η –
1·0
·75
·5
·25
200
100
5
2·5
2·5
5
7·5
10
12·5

Fig. 4.

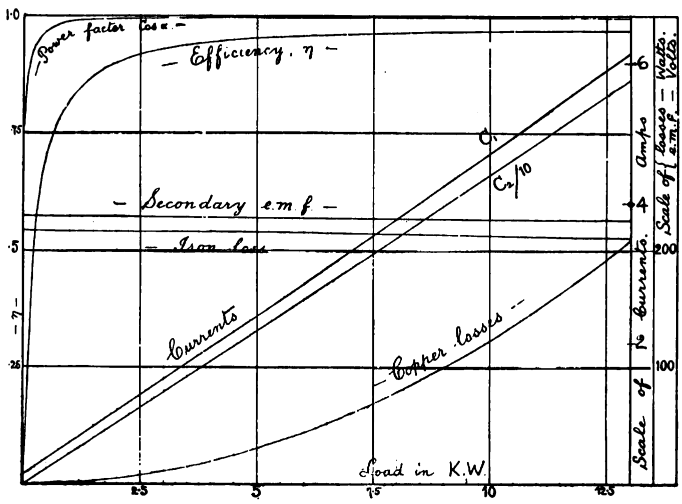

Power factor Cos α –
– Efficiency, η –
C_1
$C_2/10$
– Secondary e.m.f. –
– Iron loss
Currents
– Copper losses –
Load in K.W.
Scale of Currents. Amps
Scale of { losses – Watts. / e.m.f. – Volts.
– η –
1·0
·75
·5
·25
6
4
200
100
2·5
5
7·5
10
12·5

Fig. 5.

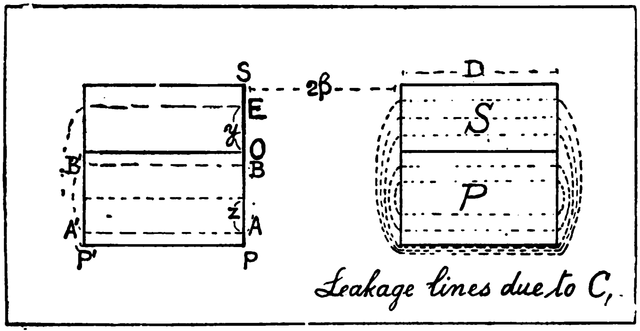


Fig. 6.

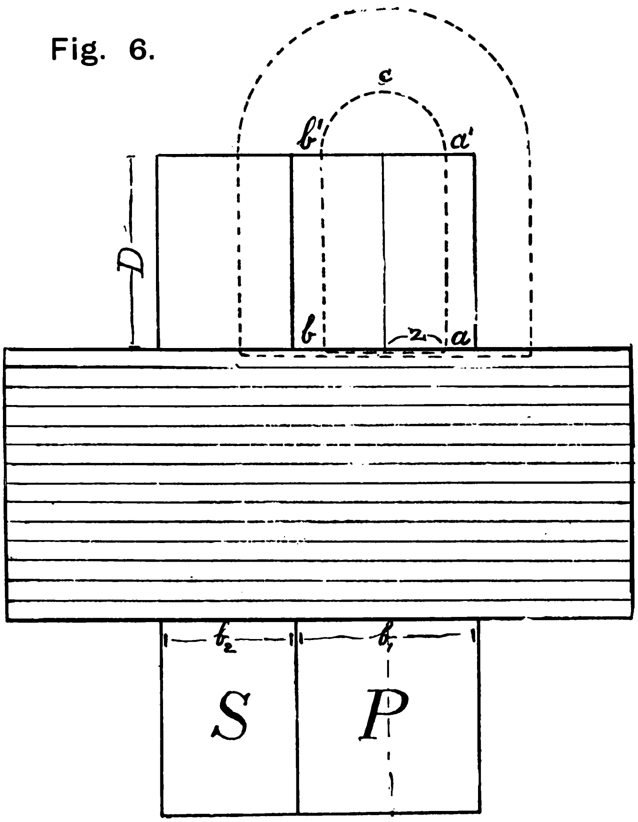
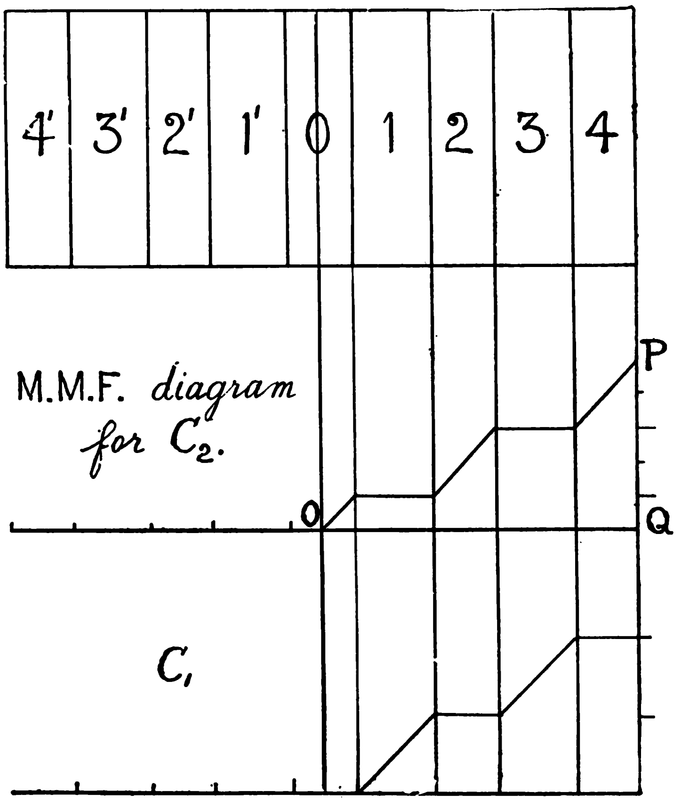


Fig. 7.



former have been expressed in terms of θ by equations identical in form to those obtained in Section I., and which can be reduced to the latter by making $x_{12}=x_{21}=0$ and dropping insignificant terms.

From equation (XI.), § 63, we can, as in § 18, express θ in a series of ascending powers of P_2, and thence transform the pre ceding equations, in which the independent variable is θ, to others in which the independent variable will be P_2 or the output.

This transformation, and any further discussion of the general equations we have obtained is unnecessary, as it would follow on exactly similar lines to what has been already given in Section I.

ART. II.—*Contributions to our Knowledge of the Anatomy of Notoryctes typhlops, Stirling.*

PARTS I. AND II.

BY GEORGINA SWEET, D.Sc.,

Melbourne University.

(Communicated by Professor W. Baldwin Spencer, F.R.S., &c.).

(With Plates VI-IX.).

[Read 12th May, 1904.]

INTRODUCTION.

The investigation, of which the following forms a record, h been carried on in the Biological Laboratory of the Melbourn University, for the use of which I have to thank Profess Spencer, who has also very generously placed his splendid stoc of animals at my disposal, and has given me facilities in obtai ing literature, some of which I might otherwise not have seen.

The subject matter falls naturally into three parts, each which is complete in itself, though they are to a certain exte interrelated. Part III., on the Eye, is now ready for the pre an abstract of it having been read at the Dunedin Meeting of t Australasian Association for the Advancement of Science, January, 1904.

PART I.—NOSE, WITH ORGAN OF JACOBSON AND ASSOCIAT PARTS.

Of the various structures to which of more recent years co siderable attention has been directed, not the least interesting the Organ of Jacobson, and with it the relations of the cartilag and bones of this region. Especially is this so in view of t valuable papers by Dr. Broom, on its comparative anatomy the various groups of the Metatheria and Eutheria, in which

claims that, on account of the very slight tendency of these parts to vary with external variations, "we have a factor of considerable value in the classification of the Eutheria, probably of more value than either dentition or placentation." If this be so, and there seems strong evidence in its favour, we ought to find in this organ data on which to base a true conception of the relationships of such an aberrant form as Notoryctes, especially valuable since its embryology remains at present unknown. In itself a desirable result, this should also assist in defining the affinities of associated groups. Heretofore, apparently, nothing has been known of its structure in Notoryctes, nor even of its presence. This being so, it was suggested when working out the relations of the naso-lachrymal duct in connection with the eye, that I should include Jacobson's Organ in this research. Furthermore, we find that the structure and relations of the cartilages and bones associated with the nose are well worthy of record, as well as those of the organ itself.

In Broom's valuable thesis on Jacobson's Organ,[1] he has distinguished four types of this structure in mammals corresponding in part to the main groups: Monotreme, the most highly developed, Marsupial, Rodent, and general Eutherian; the main features of distinction being the character of the connection of the lumen of Jacobson's Organ with the naso-palatine canal, or with the nasal cavity, and the arrangement and degree of complexity of the cartilages. In view of the apparent value of this organ in classification, and the much modified character of Notoryctes, I have thought it desirable to make a more complete comparison of the various details of structure, with similar parts in other forms, than might have been necessary in some other animals.

Position of the Organ of Jacobson.

The organs of Jacobson are, as stated above, well developed in Notoryctes, being approximately equal in size to those of the Rabbit. They are situated near the floor of the nasal cavity, one on either side of the median line, just in front of the vertical plane of the osseous nasal septum, *i.e.*, 3.6 to 3.8 mm. from the anterior edge of the snout. They are separated from each other

[1] Trans. Roy. Soc. Edin., vol. xxxix., 1898-1900, p. 234.

and partly enclosed by the bony palatine processes of the premaxillary bones (the prevomers of Broom) and by the cartilages of Jacobson. The Organ, with a small ledge of cartilage lying externally to it, causes an elongated triangular projection (Figs. 3, 4, 5, *i.s.r*) on the mesial wall of the nasal furrow, the base of the triangles being formed by the lateral wall of Jacobson's Organ. This ridge in the lining mucous membrane of the nasal furrow, which is always indicative in mammals of the position of this Organ, has been called by Broom "the inferior septal ridge." It is continued in a less degree anteriorly and posteriorly; anteriorly because of the presence of the cartilaginous shelf supporting the Organ, in front of the Organ itself, the trough so caused being here occupied by glands; while posteriorly the lower part of the ridge is still present, because of the bony shelf from the palatine processes of the premaxillary bones. Even where the Organ of Jacobson is itself present, the size of its consequent ridge is increased by a considerable development of glandular alveoli, outside Jacobson's cartilage and continuous with the gland masses in front of and behind Jacobson's Organ—compare Phascogale[1], Didelphys,[2] Perameles,[3] Pseudochirus.[4]

Cartilages and Bones in connection with the Nasal Organ.

The cartilaginous nasal septum (Figs. 1 and 2, *n.s.c.*) is present, dividing the nostrils right up to the anterior end of the snout. Its cartilage is hyaline, and the cells numerous, deeply staining and showing evidence of rapid growth.

As have others, we find that transverse vertical sections offer the best means of studying this part, aided also by longitudinal vertical sections. Beginning anteriorly, we find that the alinasal cartilage supporting each nostril is well developed, and is free anteriorly on its lower border (Fig. 1, *a.c.*), not being here united to the ventral processes of the septum, but swelling out instead into an edge which is club-shaped in transverse section, and supports a well marked ridge (*p.l.r.*), the cartilage being covered with a considerable thickness of gland material (*m.g.*), the whole rendering the cavity of the nostril crescentic in outline.

1 Broom: Proc. Linn. Soc., N.S.W., vol. xxi., 1896, p. 593.
2 *Loc. cit.*, p. 597.
3 *Loc. cit.*, p. 599-600.
4 *Loc. cit.*, p. 603.

In outline the cartilages present in transverse section, that of an ornamental T. This ridge is referred to by Dr. Stirling[1], and is well shown in his accompanying figure of the animal. Dorsal to these alinasals lie the forward processes of the nasal bones (*n.b.*). Further back, the ridge containing the swollen edge of the alinasals, comes to lie more ventralwards, the superior position being taken by another ridge (Fig. 5, *s.l.r.*) with glandular interior, and containing a large duct from the mucous glands posterior to this level. A short distance behind the beginning of the second ridge there arises a process from the arch of the alinasal cartilage on each side, connecting each with one of the ventral processes of the nasal septum (*n.f.c.*), so that at this point, and not anterior to it, the nostril is completely enclosed on each side with cartilage. This condition is closely comparable with that in Macroscelides, as shown in the figures given by Broom[2]. Soon there pierces the alinasal cartilages a canal on each side, through which passes one of the naso-lachrymal ducts, which open in front of this, on the ventral surface of the primary lateral ridge into the ventral nasal furrow (*v.n.f.*) on each side. Between the plane of the opening of the naso-lachrymal duct, and that of its passage through the encircling cartilage, I have been able to trace a splitting off from the ventral surface of the cartilage of the nasal floor (formed by ventral processes from the cartilaginous septum), of what is at first a thin lamella of cartilage, in three parts. Those on either side lose their connections with the nasal floor except for a while at the extreme outer edge of each, and finally become continuous with the anterior edge of each premaxillary bone. The central portion remains longer in connection with the nasal cartilage, so that, in a transverse section taken just at the level of the passage of the naso-lachrymal ducts through the alinasal cartilages, the following relations exist. The nasal septum (Fig. 1, *n.s.c.*) is very thin and deep, giving off above the two alinasal cartilages (*a.c.*), and ventrally two processes (*n.f.c.*) forming the floor of the nasal cavity. Compare in this respect Ornithorhynchus, in which the nasal septum becomes united with these nasal floor cartilages.[3] This is to be

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1 Stirling: Trans. Roy. Soc. S. Aus., 1891, p. 159, pl. iii.

2 Proc. Zool. Soc. Lond, 1902, vol. i., pl. xxi., fig. 1.

3 Broom: Trans. Roy. Soc. Edin., vol. xxxix., p. 235.

contrasted with the condition found in most Marsupials, and also in Rodents, in which they are at most in contact with the nasal septum. In the Macropodidae, Symington[1] has noted the connection of the nasal floor cartilages to the ventral edge of the nasal septum, by perichondrium.

Beneath this, and separated from the cartilage by connective tissue and blood-vessels, are the extreme anterior ends of the premaxillary bones (*p.b*), just losing their fibrous cartilaginous connections with the lateral edges of the nasal floor, and separated from each other in the middle line by a large vein (*v.*). Above this vein is a somewhat wedge-shaped nodule of hyaline cartilage (*p.c.*), which in the next section posteriorly sends down a fibrous process to occupy the space between the two premaxillaries, pushing the vein ventralwards. In this section, also, the nasal bones (*n.b.*) have grown down, enclosing the alinasal cartilages nearly to the level of the primary ridge, and three sections further back the nasal and upward processes of the premaxillary bones meet, completing the bony as well as the cartilaginous capsules round the nose. Still proceeding backwards, we find that the wedge-shaped cartilage has now completely descended between the premaxillaries to form the connection between their mesial edges. The above description can be readily corroborated on reference to longitudinal sections. Splitting off anteriorly from the ventral edge of the septum is the narrow sheet of fibrous cartilage passing obliquely downwards and backwards to lie between the palatal processes of the premaxillary bones in their anterior part. On the hinder face of this sheet of cartilage is the hyaline cartilaginous swelling, which in transverse section appears wedge-shaped. In front of the sheet, the bones are separated by a well-defined vein, connected with a large blood sinus, which curves round vertically in front of the cartilaginous septum. Posteriorly in these longitudinal sections we can see that the central cartilaginous bar or narrow sheet becomes lost as the two palatal processes of the premaxillae become more intimately united. There can be, I think, no doubt but that this central cartilage represents here the prenasal cartilage of other animals. Its general

1 Jour. Anat. and Phys., vol. 26, p. 372, and pl. x., fig. 1.

relations greatly resemble those shown by Broom to exist in the foetal calf.[1] With reference to the transverse plates of cartilage described by Broom as existing on each of the central rod, and supporting the papilla between the naso-palatine canals, which is so marked in Marsupials,[2] such for example as in Didelphys murina,[3] in Perameles nasuta,[4] in Petaurus,[5] and Trichosurus,[6] Phascolomys[7] and Macropus.[8] I can find no trace of hyaline cartilage in such a position, but the fibrous sheet of cartilage which connects the main part of this prenasal between the premaxillary processes with the nasal septum, sends out laterally a thin ill-defined fibrous layer (Figs. 2 and 3, *f.p.c.*), which extends backwards beneath the palatal processes into the papilla, behind which it does not exist. Apparently this represents the papillary cartilage of other Marsupials, and that of Miniopterus[9] and Macroscelides.[10]

Returning to the vertical transverse sections, we find that not only the primary and secondary lateral ridges, but also the septal cartilage are covered by a great thickness of glandular alveoli, forming on the septum the superior septal ridge (*s.s.r.*). These glands have well defined ducts, often .06 mm. in diameter, running longitudinally, to open far forwards into the vestibule. The thickness of the glandular layer varies on the superior septal ridge .24 to .52 mm., and on the superior lateral ridge .24 to .6 mm. The lining membrane of the nasal cavity over these ridges is smooth, like that of the Guinea-pig, and so unlike that of the Rabbit, which is much plicated. About this vertical plane, the cartilaginous projection, supporting the primary ridge from the lateral wall, diminishes greatly in size and finally disappears, so that on each side the cartilages of the nasal floor now form a very shallow double U-shaped curve, each of the nasal furrows of each side occupying the loop of one U, the mesial edge of the

1 Proc. Linn. Soc. N.S.W., vol. x., n.s., pl. xliv., fig. 7, and p. 561.
2 *Loc. cit.*, fig. 6, and p. 560.
3 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, p. 597.
4 *Loc. cit.*, p. 599.
5 *Loc. cit.*, p. 604.
6 *Loc. cit.*, p. 607.
7 *Loc. cit.*, p. 613.
8 *Loc. cit.*, p. 610.
9 *Loc. cit.*, vol. x., n.s., 1895, pl. xliv., figs. 4, 5, p. 560.
10 Proc. Zool. Soc. Lond., 1902, vol. i., pl. xxi., figs. 8, 10, p. 226.

inner U being continuous with the ventral edge of the nasal septum, while the naso-lachrymal duct lies underneath in the angle formed between the two loops. The arrangement of this double U-shaped cartilage, and the subsequent reduction of the cartilages (to be immediately described in Notoryctes), may be compared with that shown in Klein's figures of the Guinea-pig,[1] though here the central cartilage is not connected with the septum as it is in Notoryctes. Gradually here the outer U becomes lost on each side at about the level of Stenson's duct, or a little posterior to that duct. Compare this with Didelphys murina,[2] Perameles,[3] Aepyprymnus,[4] and contrast with Trichosurus.[5] In Notoryctes, however, this outer cartilage is present behind the naso-palatine canal as a rudiment. At the same time, the alinasal cartilages, having receded dorsally, only extend down in the upper third of the nasal wall. At this point, each nasal cavity (Fig. 2, *n.c.*) in transverse section resembles a two-pronged fork, the two prongs being represented by the two nasal furrows (*v.n.f.*).

A change is also noticeable in the outlines of the palatal processes of the premaxillae, which are still united only by the median cartilage above described. The adjacent edges of the premaxillaries, which are thin anteriorly, become much thickened posteriorly (Fig. 2, *p.p.p.*), wedge-shaped in cross section, their mesial faces being convex to each other. The upper edge of this wedge now becomes more marked, rising up in a crescentic fashion (compare especially Phascolgale[6], in which, however, they are much smaller than in Notoryctes and Perameles[7]), till it touches the ventral cartilage of the nasal floor, the lower edge of the wedge disappearing. In this plane (Fig. 2, *J.c.*) there appears a swelling in the hyaline cartilage of the nasal floor, from which passes back a bar, also of hyaline cartilage, part of Jacobson's cartilage. The swelling in the mesial wall of the ventral nasal furrow, *i.e.*, the inferior septal ridge (*i.s.r.*), caused by the cartilage,

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1 Quart. Jour. Micro. Science, vol. xxi., pl. xvi., fig. 1, 2, 3.
2 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, p. 597.
3 *Loc. cit.*, p. 601.
4 *Loc. cit.*, p. 610.
5 *Loc. cit.*, p. 607.
6 *Loc. cit.*, p. 593.
7 *Loc. cit.*, p. 599.

and which increases in size greatly and almost immediately, occasions a pushing in of the ventral nasal furrow, the cavity of which now becomes in cross-section foot-shaped, the inferior septal ridge filling up the instep. Suddenly, just posterior to this, there appears the swollen anterior end of Jacobson's Organ (Fig. 3, *J.O.*). The cartilage of the nasal floor may be now called in part Jacobson's cartilage, since it has here lost its connection with the nasal septum (Fig. 3, *J.c.*). In this respect Notoryctes resembles Ornithorhynchus[1] and Echidna,[2] in which Jacobson's cartilage "is continuous in front of the naso-palatine foramen with the cartilage in the floor of the nose," as also with the septum, "while behind it is separate." It resembles also the Rabbit,[3] and also the Guinea-pig,[4] in that the cartilage is continuous with the cartilage of the nasal floor, though in each of the latter the cartilage of Jacobson is altogether independent of the cartilaginous nasal septum. The cartilage of Jacobson now consists, on each side, of a crescentic shelf, from the middle of the concavity of which rises, at right angles, a band of cartilage (*o.J.c.*), under which runs, near its anterior end, Jacobson's duct (Fig. 3, *J.d.*) into the "toe" of the nasal furrow, while in the groove formed between the band and the upper horn of the crescent lies the Organ of Jacobson. In Notoryctes, the crescentic cartilage of Jacobson is oblique, similar to that of Petaurus[5], and unlike that of Pseudochirus and Petauroides[6], which are more vertical.

The band or shelf of cartilage supporting the lateral wall of Jacobson's Organ, is comparable in part to what is called the septal turbinal in Macroscelides,[7] though arising from the main cartilage at a different angle. It is further comparable to Macroscelides in that this shelf is only connected with the ventral cartilage behind the exit of Jacobson's duct from the Organ, near its anterior end. This outer bar is similarly found in most Marsupials, but that in Notoryctes differs from them in

1 Proc. Zool. Soc., 1891, p. 578.
2 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, p. 592.
3 Q.J.M.S., vol. xxi., p. 550.
4 *Loc. cit.*, p. 220.
5 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, p. 604.
6 *Loc. cit.*, p. 604.
7 Proc. Zool. Soc., vol. i., pl. xxi., figs. 3 and 4, p. 226.

one particular, viz., that in them this bar is connected above and in front with the upper end of Jacobson's cartilage, and below and behind with its lower outer edge. In Petaurus,[1] however, and Phalangers,[2] and to a less extent in Trichosurus[3] and Macropods,[4] there is a ridge process exactly similar to that of Notoryctes in its origin from the inner upper side of Jacobson's cartilage, becoming detached from it, and then more posteriorly becoming attached to the lower ridge of the cartilage. The "bar" in Notoryctes apparently truly corresponds to that of the other marsupials in that it comes off anteriorly to Jacobson's duct from the ridge process, curls round the Organ and over the duct, and becomes attached posteriorly to the duct, to the ventral edge of Jacobson's cartilage, being therefore merely a further exaggeration of what is present in Petaurus, and the Phalangers generally. Meanwhile in Notoryctes, the cartilaginous connection between the palatine processes of the premaxillaries has almost disappeared, the two bones by this time practically fusing. The crescentic character of the bones now harmonises closely with that of the cartilages (Figs. 3 and 4, *p.p.p.* and *J.c.*). From the ventral convex surface of the rapidly dwindling cartilage of the outer nasal floor, is given out just here a small process of hyaline cartilage (Fig. 3, *s.c.*), which is found strengthening the upper and anterior wall of Stenson's duct which lies just posterior to this. Here we have another point of difference from other Marsupials, in which there is no cartilaginous support to the naso-palatine canal, though in Petaurus[5] and others we find a process supporting the inner wall. This may also be compared with the Rabbit,[6] in which Stenson's cartilage is a continuation from the cartilage of the nasal floor, and contrasted with the Guinea-pig,[7] in which the cartilage forms a closed capsule around the two ducts, and is quite separated from all other cartilages. It is to be noticed here, that the upper horn of the crescentic Jacobson's cartilage is

1 Proc. Linn. Soc. N.S.W., vol. xi. n.s., 1896, p. 604, pl. xliv., figs. 10, 11.
2 *Loc. cit.*, p. 616.
3 *Loc. cit.*, p. 607.
4 *Loc. cit.*, p. 618.
5 Broom: Trans. Roy. Soc. Edin., xxxix., p. 240.
6 Klein: Q.J.M.S., vol. xxi., p. 555.
7 *Loc. cit.*, p. 228.

thinning out greatly, as also the cartilage underlying the ventral nasal furrow, so that, about the level of the exit of Stenson's duct from the nasal furrow, there is no cartilage left in this region, except for remnants of the outer nasal floor cartilage (Fig. 4, *n.f.c.*), and the outer bar of Jacobson's cartilage (*o.J.b.*). Thus, here the median and lower lateral parts of the cartilaginous crescent disappear first as compared with the Rabbit,[1] and, contrasted with the Guinea-pig,[2] the upper lateral or lower lateral parts of which go first. At first this remnant of cartilage appears to become directly connected by its perichondrium with the lower edge of the crescentic bone (Fig. 5) as found by Klein in the Guinea-pig; soon the cartilage disappears altogether, leaving a very thin bony shelf (Fig. 5, *p.p.s.*) in its place. Compare this with Perameles,[3] and also with the Macropodidae[4] in so far that the cartilages of Jacobson form an incomplete tube, becoming reduced posteriorly. At this level, nerve fibres occupy almost the whole space between the bone and the mesial wall of the Organ.

Posterior to the Organ of Jacobson the inferior septal ridge still remains because of the persistence of the bony shelf, which anteriorly helped to support Jacobson's Organ; while, as far forward as the anterior end of the Organ, the primary lateral ridge (*p.l.r.*), which has been for a short distance devoid of special support, is invaded by a thin lamina of bone from the maxillary bone, becoming the maxillo-turbinal (*m.t.*). In the hinder part of this region the palatal processes are overlain in the middle line by the anterior portion of the vomer, so that there is now a complete bony partition between the right and left nasal cavities, from dorsal to ventral or palatal surfaces.

Ducts of Jacobson and of Stenson.

The duct connecting the lumen of Jacobson's Organ with the nasal cavity (Fig. 3, *J.d.*) is very short, .06 mm., since the wall enclosing the ventral sulcus of the extreme anterior end of the Organ lies almost immediately in contact with the mesial edge,

1 Klein: Q.J.M.S., vol. xxi., p. 554.
2 *Loc. cit.*, pl. vii., fig. 2.
3 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, p. 600, fig. 8.
4 Jour. Anat. and Phys., vol. 26, p. 372.

which is also the most ventral part of the nasal furrow (*v.n.f.*
The duct then passes outwards almost horizontally to open in
the nasal furrow. At this plane, in transverse sections, is als
seen the external aperture of the naso-palatine, or Stenson's du
(Fig. 3, *n.p.d.*), into the mouth. This duct, which is .40 mm
long, runs inwards, upwards, and backwards, piercing betwee
the premaxillae and palatine processes to its origin from th
ventral edge of the nasal furrow, some distance behind the ope
ing of Jacobson's duct into it (Fig. 4, *n.p.d.*). There is, therefor
no direct communication between the cavity of the Organ an
Stenson's duct, except through the cavity of the nasal furrow
this is confirmed by the difference in structure between the wa
of Jacobson's duct and of Stenson's duct, and the intervenin
nasal furrow.

This condition may be compared with that described by Broo
as an exception among Marsupials in Aepyprymnus[1], by Klein i
the Guinea-pig[2] and Rabbit,[3] by Harvey in the Rat and Hedgehog
and by Broom in Dasypus.[5] It may also be contrasted with tha
in Ornithorhynchus[6] and Dog,[7] and the usual Marsupial an
higher Mammalian types, as described by Jacobson, Gratiole
Balogh, Fleischer, and Broom, in which Jacobson's Organ oper
into Stenson's duct, otherwise remaining closed, *e.g.*, in Macr
pus[8], Phascologale[9], Dasyurus[10], Didelphys[11], Perameles[12], an
Phascolomys.[13] The openings of Stenson's ducts into the mout
cavity are separated by a well-marked papilla, the centre o
which becomes somewhat hollowed out (Fig. 3). This, as state
above, is supported, anteriorly at least, by a fibrous continuatio
from the prenasal cartilage (*f.p.c.*). The similarity of the gener
relations of the parts seen in such a section of Aepyprymnus a

1 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, p. 610.
2 Q.J.M.S., vol. xxi., p. 219.
3 *Loc. cit.*, p. 555-6.
4 Q.J.M.S., vol. xxii., p. 50.
5 Trans. Roy. Soc. Edin., vol. xxxix., p. 242.
6 Proc. Zool. Soc. Lond., 1891, p. 578.
7 Q.J.M.S., vol. xxii., p. 301-2.
8 Jour. Anat. and Phys., vol. xxvi., p. 372.
9 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, p. 593.
10 *Loc. cit.*, p. 594.
11 *Loc. cit.*, p. 597.
12 *Loc. cit.*, p. 600.
13 *Loc. cit.*, p. 613.

that shown by Broom[1] to those seen in a similar section of Notoryctes is considerable, especially in reference to Jacobson's cartilage, the opening of the duct into the nasal cavity, and its relation in vertical plane to the dorsal opening of the naso-palatine duct into the nasal furrow, and to its ventral opening into the mouth.

General Structure of Jacobson's Organ.

As in the Organ of Jacobson previously described in other animals, the lumen of the tube (Figs. 3, 4, 5, *J.O.*) in Notoryctes is more or less laterally compressed in its main portion, so that we distinguish the lateral (*l.w.*) and median walls (Fig. 6, *m.w.*), which meet at the upper and lower sulci. In the examples of which I have sections, the left tube is greater in vertical diameter than is the right, the latter, moreover, in great part of its length being almost circular, while, right to the hinder end, the left organ retains, in an increasingly marked manner, its compressed character, its cavity being posteriorly a mere slit. As usual, the sensory epithelium is confined more or less strictly to the median wall. In shape this Organ is generally speaking oval, but much drawn out and bluntly pointed posteriorly, while anteriorly it often ends quite abruptly. The length of its lumen is 1.2 mm., its total length being 1.4 mm. Its ventral edge is almost straight, the dorsal edge curving downwards posteriorly to meet the former. Its outline in transverse section varies considerably. Posteriorly, it is much flattened from side to side, its lateral wall being in parts slightly indented, though it can scarcely be called kidney-shaped (Figs. 5 and 6, *J.O.*). This to a certain extent is comparable with that shown for part of the Organ in Miniopterus,[2] by Broom, by Klein in the Dog,[3] and in a much less degree with that shown by Symington and Smith, in Ornithorhynchus[4] and Echidna,[5] and by Broom in marsupials generally. But, whereas in the former of these it is due more or less to an incurving of Jacobson's cartilage, in Notoryctes it is simply due to a thickening of the subepithelial

1 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, pl. xlvii., fig. 11.
2 Proc. Linn. Soc. N.S.W., vol. x. n.s., 1895, pl. 47, fig. 4.
3 Q.J.M.S., vol. xxii., p. 305.
4 Proc. Zool. Soc., 1891, p. 579.
5 Anat. Anz. XI. Band., 6, 1895, p. 162-3.

layers of the lateral wall, there being no inturning of th capsule. In the Rabbit[1] and Marsupials, however, there is similar somewhat kidney-shape in the central portion of th Organ, due only to subepithelial and glandular thickening. Thi indentation, moreover, is not constant, as, occasionally, as abov stated, while one side retains more or less of the concavity i its lateral wall, the Organ of the other side may be quite oval c even circular in transverse outline.

In vertical diameter the Organ varies from .32 to .6 mm Horizontal diameter, .12 to .28, very slightly less than in th Rabbit, and slightly under half of that of the Dog and Guinea pig. Into the upper and lower sulci of the Organ there open considerable number of ducts from the gland mass on either sid of the nasal septum. Seven or eight of such ducts may at time be seen in one single longitudinal section opening into the uppe or dorsal sulcus, and a lesser number into the ventral sulcu These ducts, which are short, wide, and have darkly staining wall lie at right angles to those from the same gland mass, which ru forwards longitudinally, and more or less parallel, till they ope into the vestibule close to the external orifice. The latte longitudinal ducts are usually fifteen to twenty in number o each side of the cartilaginous septum.

Blood Vessels.

Jacobson's Organ is well supplied with these (Figs. 5 and 6 *v.*, *a.*, *ct.*). Alongside its lateral wall, there run an artery an two veins, the former curving round anteriorly, from dorsal t ventral surfaces, and between the front end of the Organ and it supporting cartilage in this region, while both laterally an ventrally in the median wall is to be found a more or les extensive plexus of blood vessels (Figs. 5, 6, *c.t.*).

Nerves.

In longitudinal sections, especially, there is to be noted a larg branch of the olfactory nerve passing forward horizontally an entering into relation with the dorsal and mesial surfaces of th

1 Q.J.M.S., vol. xxi., p. 558.

posterior part of the Organ, descending anteriorly to the mesial wall, as seen in transverse sections (Fig. 6, *n.f.*).

Minute Structure of Jacobson's Organ.

For convenience of description we may take first the lateral wall, with the structures outside this, and then similarly the median wall.

1.—The Lateral Wall.

The epithelium lining the Organ of Jacobson on this side (Fig. 6, *l.w.*) is .04 to .06 mm. thick, being slightly less than in the Dog, and the same as in the Guinea-pig and Rabbit. It consists of a columnar epithelium, similar to that lining the nasal cavity (which is .06 mm. thick), having here apparently two layers of cells; (α) an outer columnar layer with long, strong cilia (*c.f.*, Guinea-pig and Dog, and contrast the Rabbit), and oval nuclei. These are interspersed with goblet cells, which are numerous in parts of the lower half of the wall; (β) an inner layer with rounded nuclei. It will be seen that this differs from that of the Guinea-pig as described by Klein[1] in that his middle layer of spindle-shaped cells is not visible here. Probably this is due to the fact that all the material at my disposal is spirit-hardened, and in such cases Klein has found great difficulty in distinguishing the spindle-shaped cells from those of the columnar layer. Next to this is a well-marked fibrous layer corresponding to the subepithelial layer of other forms, with blood vessels and gland alveoli. The cavernous tissue shown by Klein to be so well developed in this position in the Guinea-pig[1] and Rabbit,[2] and by Broom in Phascolarctos,[3] and in Petauroides,[4] does not exist here in Notoryctes, the blood vessels of this side being limited to an artery (*a*), running longitudinally along the middle line of the tube, and one or two small veins. This is more like what we find in the ordinary Marsupials, which have a single hilar blood vessel. It may be seen in Macroscelides,[5] and is much greater in extent than in the lateral wall of

1 Q.J.M.S., vol. xxi., p. 101-3.
2 *Loc. cit.* p. 563-4.
3 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, p. 613.
4 *Loc. cit.*, p. 607.
5 Proc. Zool. Soc., 1902, vol. i., p. 226.

Miniopterus.[1] The glandular development is here (*m.g.*), as in the Rabbit,[2] and, contrasted with Miniopterus[1] and the Guinea-pig, most marked in the cartilaginous capsule, at the upper and outer part of the Organ, though unlike the Guinea-pig, where the glands are more numerous when the cartilage is absent, in Notoryctes there seems to be no such invariable relation. There are also, as described above, numerous glands lying in the inferior septal ridge (*i.s.r.*) outside Jacobson's cartilage. In this respect, Notoryctes agrees with Didelphys murina,[4] Trichosurus,[5] and Dasyurus maculatus,[6] while differing from the Phalangers generally, and from Perameles[7] and Dasyurus viverrinus.[8] At the same time, we find the general Diprotodont feature, characteristic also of Phascolomys,[9] in which numerous gland ducts open into the Organ from above. With regard to these glands around Jacobson's Organ, it may be remarked that they appear to be regarded by Klein, as also those on the septum, as true serous glands in the Rabbit[10] and Dog;[11] while Broom finds, in the septum, mucous glands in Miniopterus,[1] and in various Marsupials also.[12] In Notoryctes, those in the mucous membrane of the septum and ridges covering the turbinal bones, appear to be true mucous glands, though those around the Organ of Jacobson and a small group on each side of the bottom of the nasal septum are apparently serous in character, and have smaller alveoli, more deeply staining nuclei, broader, deeply staining ducts, which all open into Jacobson's Organ. The gland ducts chiefly enter the tube at the upper and lower sulci, though occasionally they open through the lateral wall itself as previously found in the Rabbit[10] and Sheep. Their number would account for the fact that the tube is always

1 Proc. Linn Soc. N.S.W., vol. x., n.s., 1895, p. 574.
2 Q.J.M.S., vol. xxi., pp. 563-4.
3 *Loc. cit.*, p. 103.
4 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, p. 598.
5 *Loc. cit.*, p. 607.
6 *Loc. cit.*, p. 596.
7 *Loc. cit.*, p. 602.
8 *Loc. cit.*, p. 596.
9 *Loc. cit.*, p. 613.
10 Q.J.M.S., vol. xxi., p. 564.
11 *Loc. cit.*, vol. xxii., p. 306.
12 *Loc. cit.*, vol. xi. n.s., 1896, p. 614; Trans. Roy. Soc. Edin., vol. xxxix., p. 233.

full of secretion. From this, as from the large size of the Organ, we may perhaps infer that in Notoryctes the glandular function is relatively more important than the sensory one.

Coming down from the side of the septum, and running longitudinally, are a small number of scattered nerve fibres similar to those described by Klein in the Rabbit.[1]

The main features of the histology also agree closely with those described by Symington in Macropodidae.[2]

2.—Median Wall.

The sensory epithelium lining this wall (Fig. 6, *m.m.*) extends also as described in the Guinea-pig by Klein[1] in the anterior half, a short distance down the lateral wall of the superior sulcus, but ending at the angle of the inferior sulcus for the whole length. Its thickness varies from .08 to .1 mm., slightly greater than in Dog, and slightly less than the Guinea-pig. In the posterior part the sensory epithelium ends also at the angle of the superior sulcus. The boundary between the epithelium of the lateral wall and the sensory epithelium of the median wall is always very sharply marked off.

The sensory epithelium in Notoryctes resembles closely in its general structure that of the Guinea-pig,[3] Rabbit[4] and Dog,[5] though the minute structure of the cells cannot be made out in these spirit specimens. The epithelial cells which bear short cilia appear much longer and thinner than those of the lateral wall, and have a striated border, probably due to the terminal rods of the cells in the lower layer. These epithelial cells have oval nuclei, which are disposed in three ill-defined layers similarly to the above mentioned forms. The sensory cells have large spherical nuclei more transparent and less deeply staining with haematoxylin, and with a well-marked nuclear membrane and network. They are arranged in one or two layers (as in the Dog), usually in one layer near the upper and lower sulci, and two layers in the median part of the wall. In one or two places

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1 Q.J.M S., vol. xxi., pp. 556, 564.
2 Jour. Anat. and Phys., vol. xxvi., p. 373.
3 Q.J.M.S., vol. xxi., p. 105-6.
4 *Loc. cit.*, p. 564, etc.
5 *Loc. cit.*, vol. xxii., p. 307-310.

in the length of this wall, the gland ducts pass through to open into the tube, the last part of their wall being lined by a continuation of the sensory epithelium.

The space between the Organ of Jacobson and the cartilage of Jacobson, or the bone of the crista nasalis, is closely packed in its upper half with nerve fibres (Fig. 6, *n.f.*). These are much more numerous in the median and posterior portion of the wall, decreasing in quantity anteriorly. At the hinder end of the tube, a large bundle passes off to run in the septal mucous membrane until finally it joins the main olfactory trunk. I have been able to trace these fibres among the cells of the sensory layer, but not actually into the cells, where doubtless they do end. As the nerve fibres decrease in number their place is taken by glands. The cavernous tissue (*c.t.*) so conspicuous in Klein's figures of the *lateral* wall in the Guinea-pig[1] and Rabbit,[2] and much more rudimentary in the *median* wall of the Dog,[3] is very abundant in the lower half of the median wall in Notoryctes. Here there are one or two arteries and several somewhat large veins forming a plexus, and supported by ordinary loose fibrous tissue. In the position of the nerves and veins in this median wall, we may compare this with Phascolomys.[4] In Notoryctes, as previously stated, the distinction between the medial and the lateral epithelium persists right to the posterior end of the Organ, as contrasted with the Rabbit, where only columnar epithelium is found at the posterior end of the Organ, and with Phascologale[5] and with Macroscelides.[6]

Jacobson's duct, as heretofore described, is extremely short, and is lined by a continuation of the ordinary nasal epithelium similar to that of the lateral wall. This is to be contrasted with the ordinary marsupial, *e.g.*, Dasyurus,[7] in which Jacobson's duct is lined with squamous epithelium.

Stenson's duct, however, is lined by stratified pavement epithelium continuous with that lining the palate. The surface

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1 Q.J.M.S., vol. xxi., pl. vii., fig. 5, pl. xvii., fig. 6.
2 *Loc. cit.*, pl. xxx., fig. 5-8.
3 *Loc. cit.*, vol. xxii., pl. xxvi., figs, 14, 15.
4 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, 614.
5 Proc. Linn. Soc. N.S,W., vol. xi., n.s., p. 594.
6 Proc. Zool. Soc., 1902, vol. i., p. 226.
7 Proc. Linn. Soc. N.S.W., vol. xi., n.s., 1896, p. 595.

layers of the lining of the duct are strongly corneous, this diminishing, as in the Dog,[1] as it enters the nasal furrow, to one-third of its thickness on the palate. The bottom of the furrow near Stenson's opening is similar to that of the duct itself. There are no glands opening through the wall into the canal of Stenson, as found in the Sheep (Balogh) and Man (Kolliker), but which Klein was unable to find in the Guinea-pig.[2]

It is worthy of note that the stratified pavement epithelium lining the vestibule of the nose, which may be up to .1 mm. thick, has a very thick corneous layer which may be in itself .04 mm. thick, the epithelium covering the snout itself being up to .25 mm. in thickness, of which the corneous layer makes up .1 mm.

Summary and Relations to other Forms.

The chief points[3] to be considered in discussing the relations of the Organ of Jacobson in Notoryctes to that of other forms are: (1) the direct or indirect connection of Jacobson's duct with the naso-palatine or Stenson's duct; (2) the presence of the outer bar of Jacobson's cartilage; (3) the presence or otherwise of a cartilaginous bar of support for the naso-palatine canal; (4) presence or otherwise of the outer nasal floor cartilages behind the naso-palatine canal; (5) the papillary cartilage of the prenasal cartilage; (6) the arrangement of the blood vessels.

I.—Jacobson's Duct, in Notoryctes, is seen clearly to open directly into the nasal furrow, from which in turn Stenson's duct leads down to the oral cavity. Here then we have the structure regarded by Broom as typical of the Rodents,[4] and also found by him in one Diprotodont form Aepyprymnus, and in Dasypus among the Edentata. In reference to this feature in Aepyprymnus[5], Broom considers it to be only a slight difference in the relative position of these openings, "due to the lengthening of the front of the snout in connection with the well-developed front incisors." But it cannot be so caused here in Notoryctes,

1 Q.J.M.S., vol. xxii., p. 301.
2 Q.J.M.S., vol. xxi., p. 229.
3 *c.f.*, Broom: Proc. Zool. Soc. of London, 1902, vol. i., pt. ii., p. 226.
4 Proc. Linn. Soc. N.S.W., vol. x., n.s., 1895, p. 572.
5 *Loc. cit.*, vol. xi., 1896, p. 619, and Trans. Roy. Soc. Edin., vol. xxxix., p. 241.

and one is led to think that there is more meaning in its presence there also, than that of mere parallel development in two animals possessing a rodent type of dentition, even if, as stated by Broom,[1] we are to regard Aepyprymnus as "approximating to a rodent type of dentition."

II.—We have seen that in Notoryctes, for a part of the length of its lateral wall, it has a more or less convex character, so constricting the lumen of the Organ, this being due, not to a well marked cartilaginous support as in Ornithorhynchus, or to an incurving of the edge of the cartilage as in Echidna, or even in Miniopterus or the Dog, but to a thickening of the subepithelial and glandular layers of the lateral wall, forming a "gland fold," as in the Rabbit and Guinea-pig, and in its near allies, the Marsupials. Also we find in this lateral wall the outer bar of Jacobson's cartilage as a ridge process, which is undoubtedly the rudimentary homologue of the turbinal found in the more highly organised structure of Ornithorhynchus, and to a less extent in Echidna. In a more or less developed form this outer bar is found in all Marsupials. In the degree of development found here, Notoryctes is most closely allied with the Phalangers, especially Petaurus in which it is more developed than in the Polyprotodont Dasyure, and with the Macropods to a less extent, and with Dasypus and the Rodentia among the Eutheria.

III.—The cartilaginous support for the naso-palatine canal in marsupials is never more than rudimentary; and even so, as in Perameles, Trichosurus, Phascolarctus, Macropus, Phascolomys, and Petaurus, it is always on the inner side and not on the outer anterior side of the canal, as in Notoryctes; and also in the Rodents, in which, however, it is much larger than that in Notoryctes, and in Miniopterus among the Cheiroptera.

IV.—In Notoryctes, as slightly different from other Marsupials, and Edentates, there is a very fragmentary continuation of the hinder edge of the outer nasal floor cartilages for a short distance behind the opening of the naso-palatine canal. In a degree, this may indicate a leading-on to the Rodent type, in which the cartilage persists behind the plane of the naso-palatine canal.

It must be remembered here, also, that in the attachment of the

1 Trans. Roy. Soc. Edin., vol. xxxix., p. 241.

nasal floor cartilages anteriorly to the septum, we find a similar condition in Ornithorhynchus and Echidna only.

V.—Though not developed to nearly the same extent that it is in Ornithorhynchus, or Echidna, or even in Miniopterus, there is, I think, undoubtedly a prenasal cartilage present in Notoryctes. It certainly cannot be called a prolongation anterior to the cartilaginous nasal septum, and since that in Notoryctes, extends right forwards to the end of the snout, it could not find room there. But it does split off from the ventral edge of the anterior part of this septum, and its hyaline nodule in position exactly corresponds to that found in the foetal calf. In part it also corresponds to the well-developed prenasal found in Miniopterus, since in each there is a central more or less fibrous ridge between the palatine processes of the premaxillae, giving off in Miniopterus, and to a certain degree in Notoryctes, a lateral sheet to support the papilla between Stenson's ducts, this latter somewhat resembling Marsupials, though in them the central ridge is absent. In Notoryctes, the prenasal is less developed than in Miniopterus, though exactly similar in relations to the surrounding cartilages and bones, because in the former the premaxillaries come together and fuse further back, and so shut out the possibility of the existence of any prenasal there, whereas in Miniopterus they do not meet in the middle line. One may here remember, also, that the nodule of hyaline cartilage, described by Klein in the Guinea-pig, supporting the papilla, is, as stated by Broom, probably to be regarded as a remnant of the lateral sheet of the prenasal cartilage.

VI.—Typically, in the Marsupialia there is to be found a single large vessel running along the outer face of the Organ. In Notoryctes we find two or three distinct vessels in this position, and a well-marked plexus in the median wall. In Polyprotodonts generally, this plexus is rudimentary, and in the lateral wall, in Diprotodonts, it is generally well marked, as also in the Edentates, while in the Rodents we often find a very large vascular plexus in this wall. Probably, as observed by Broom, this feature is not of much importance in classification, since in such closely allied forms as the Mouse and Guinea-pig, we find considerable differences. Similarly with the glands, though Broom has considered that the large vascular plexus, and the numerous

glands present in Rodentia, point to an affinity with the lo
Mammals. Further, he finds a great glandular development
be typical of large forms, *e.g.*, Lepus and Trichosurus. Here
have such in a small form. Here, doubtless, the numerous gla
opening into the lumen of Jacobson's Organ are associated w
the great amount of glandular material covering the septum, a
the turbinal ridges, as is also the remarkable development
glands in connection with the degenerate eye: though I do
consider that, in the case of Jacobson's Organ, this great sec
tory power is necessarily developed at the expense of the sens
function, as in the eye—since we find in Jacobson's Organ h
consistently with Broom's generalisation that the Organ
more highly developed in small forms than in large—it is
Notoryctes well developed, occupying fully two-thirds, and
parts the whole, of the cartilaginous trough in which it lies.

Conclusion.

It would seem then from the evidence of Jacobson's Organ, th
we are justified in claiming for the Polyprotodont Notoryctes, th
while it still has traces of a Monotreme relationship, it show
close affinity with the Diprotodonts by way of Aepyprymnus a
Petaurus, and also, though at a much greater distance, with
Edentates and Rodents. It thus adds its measure of confirmat
to the position given by Broom, as doubtful as yet, to
Rodentia in his classification of the Mammalian groups, in wh
he classes the Edentates and Rodents under one group,
Archaeorhinata. It, pari passu with this, adds its testimony
that of the muscular system, which has been held by Profes
Wilson,[1] to show "enduring evidences of a real, if dista
morphological kinship" with that of the Edentates.

PART II.

BLOOD VASCULAR SYSTEM.

This system, while not showing so far many special po
having a general significance, has still a number of
conditions which are well worthy of record, in ad

1 Trans. Roy. Soc. S. Aus., 1894, p. 5.

normal conditions present. The study of the blood vessels, with the material at present obtainable, is not an easy matter, owing partly to the very brittle and absolutely bleached, and often quite transparent state of the vessels, and also to the great quantity of adipose tissue surrounding them, with a considerable admixture of strong fibres, which to the naked eye are often much more like ordinary blood vessels than are those vessels themselves. Recourse has frequently to be made therefore to the compound microscope and staining fluids for certainty of recognition. Especially is this so in the pectoral, abdominal, and pelvic regions. The following details involve observations made during a careful dissection of five individuals, aided by microscopic sections of one or two parts, such as the limbs.

The Heart.

The heart, which is normal in position, is somewhat more pointed than is often the case, the apex being well directed towards the left side, and separated dorsally from the diaphragm by a small lobe of the right lung, as in marsupials generally, its pericardium, however, being distinctly connected ventrally with the diaphragm, a condition not usual in marsupials. So far as can be seen there is no fossa ovalis on the auricular septum. In the left ventricle the mitral valve has two well-marked papillary muscles holding its chordae tendineae, one on the septum, the other on the outer wall, while the right auriculo-ventricular valve has three muscles corresponding to its three flaps. The right ventricle takes no share in the formation of the apex.

Pulmonary Circulation.

The main pulmonary artery is a short thick vessel arising from the right ventricle, and leaving the heart externally just behind the arch of the aorta. It divides almost immediately, and at a point directly ventral to the trac[illegible] and anterior to its division, into the right and left pulmon[illegible] artery. The right branch is somewhat shorter and wider [illegible]an the left, each of the branches lying ventral and somewhat [illegible] or to the bronchus of its own side [illegible] to t[illegible] root of the lung [illegible]sses downwards

to the lower part of the lung, alongside the main branch of the pulmonary vein.

The pulmonary veins are two large vessels, each of which is formed, as it leaves the lung of its own side, of two, or sometimes three, main vessels. The left pulmonary vein would appear to be both longer and wider, as also more sloping, than the right. The two unite and form a median trunk, as in Marsupials generally, similar in thickness to the corresponding trunk of the pulmonary artery, but at least twice as long as the latter. Each pulmonary vein runs ventral and also posterior to the bronchus of its own side. The division of the trachea into the bronchi occurs dorsal to the anterior half of this main pulmonary venous trunk. It then opens into the right auricle by a wide aperture, behind the emergence of the pulmonary arterial trunk, and in front and slightly to the right of the entrance of the left anterior vena cava into the right auricle. This is the usual arrangement of these parts in Marsupials.

Systemic Arteries.

The aorta emerges from the base of the heart at about the same level vertically, or slightly in front of the pulmonary artery, curving towards the front and left, round the trachea, and then backwards dorsally to the bronchus and root of the left lung. From the beginning of the arch, as usual, the coronary vessels are given off, one of which only can sometimes be seen with the unaided eye. The relative positions of the origins of the carotid and subclavian arteries vary somewhat in different individuals. The two types are : (1) The two carotid arteries, left and right, arise as a common trunk $\frac{1}{8}$-inch in length, from the root of which opens the right subelavian artery, the left subclavian leaving the arch considerably to the left end of the transverse part of this arch. This corresponds to the condition found in the majority of Marsupials and in Choeropus in particular.[1] (2) In other specimens again, and, so far as my material shows, most frequently, the right carotid and subclavian arteries arise as a common innominate trunk similar to that of many higher forms, including Man. The left carotid artery arises close to the base of this

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1 Parsons : Jour. Linn. Soc. Lond., Zoology, vol. xxix., No. 188, Oct. 1903, p. 64.

innominate vessel, the left subclavian having its origin some little distance to the left of the left carotid artery, and not close beside it, as in Man. In this, Notoryctes resembles the broad-chested Marsupials, such as the Wombat and Koala.[1] Consequent on these variations the lengths of these vessels vary also. In relation to the nerves, the carotid artery lies ventral to the recurrent laryngeal, and pneumogastric nerves, crossing them obliquely as it runs outwards towards its anterior end. The sympathetic nerve appears to lie quite to the other side of the common carotid artery on each side. Where the two common carotids and the right subclavian artery are united at their origin from the aorta the pneumogastric also lies to the outer side of each common carotid, since the angle caused by this vessel in its course forwards is then considerably greater than where the vessels of the right side only are united to form an innominate vessel. The common carotid gives off no branches, but divides anteriorly into the external and internal carotids. The external carotid lies at first slightly below and distinctly nearer the median line than the internal carotid. It soon gives off the superior thyroid artery, which runs straight forwards and inwards to the thyroid gland. The ascending pharyngeal artery appears sometimes to be given off from the internal carotid just anterior to the bifurcation of of the common carotid, instead of being associated with the external carotid, as in higher forms. A little in front of the superior thyroid, the lingual artery is given off, running above the digastric and stylo-hyoid muscles, and continues under the mylo-hyoid muscles, giving off a branch to them, and then supplying the tongue and contiguous parts. Just where the lingual artery is given off, the external carotid turns outwards, curving round behind the masseter muscle. On its posterior side, as it curves round the articulation of the jaw, the external carotid gives off the occipital and posterior auricular arteries, while from its anterior side is given off the facial artery, the main vessel then breaking up into temporal and internal maxillary arteries. The four last mentioned arteries leave the main trunk very close together, the occipital arising about half way between these and the origin of the lingual artery. It will thus be seen that the

1 Owen: Anatomy of Vertebrates, vol. iii., p. 589.

lingual and facial arteries are much farther apart than is very often the case. Also, the facial here arises quite independently of the temporal artery as contrasted with Choeropus.[1]

The internal carotid, as previously stated, gives off immediately beyond its origin from the common carotid, the ascending pharyngeal artery, a condition to be contrasted with the normal origin of this artery from the external carotid trunk. This internal division of the carotid trunk runs down deeply, external at first to the external branch until it lies close alongside the pneumogastric nerve and the superior cervical ganglion, and passes forwards between the muscles to enter the skull.

The varying relations of the subclavian artery to the main aorta have already been described. The vertebral artery appears to be similar in position to that of other marsupials, but is generally very small, and often invisible. The inferior thyroid artery and its branches are, compared with their usual proportions, very slender, especially when contrasted with the internal mammary artery, which often approaches the main subclavian artery in size. The deep cervical and superior intercostal arteries leave the subclavian trunk separately, the latter being proximal to the former.

The long thoracic, posterior scapular and subscapular, are all normal in position but of considerable size.

The brachial artery divides early into ulnar and radial branches: the relative position of these to each other, and to the nerves and muscles of the forearm, conform in general to the usual mammalian type, as do also the branches and palmar arch of the large median ulnar artery, so far as they could be made out either by dissection or by sections. Here, as contrasted with the majority of marsupials, the ulnar branches pass over the condyle of the humerus instead of piercing it.

The thoracic aorta passes round dorsally to the left bronchus, and then posteriorly, in close contact with 'dorsal wall of the thorax, to which it gives off a few very small vessels, then piercing the diaphragm to enter the abdomen.

Abdominal aorta.—This gives off the coeliac [illegible] which is long and divides into well-marked gastric [illegible]

1 Parsons: Jour. Linn. Soc. Lond., Zool., vol. xxi

hepatic branches, and somewhat lower, a much larger vessel the superior mesenteric artery, which gives off a distinct inferior mesenteric artery to the lower parts of the intestine. Below these are the renal arteries (Fig. 8, *r.a.*), the right being small and short, the left long and broad. The spermatic arteries (*g.a.*) are very small. Near and posterior to the renal arteries, as so often in Marsupials, the aorta lies quite dorsal to the posterior vena cava, by which it is completely hidden, until some distance below its bifurcation, when the external iliac arteries come to lie, still somewhat dorsally but more to the outer side of the external iliac veins. From the following description it will be seen that there is a great difference between this region in Notorcytes and in the Marsupial type, in which the abdominal aorta, after giving off the external iliac arteries, continues back, giving off the two internal iliac arteries, the small continuation then forming the median sacral artery, *e.g.*, in the Kangaroo[1] and Choeropus.[2] In Notoryctes we find that the aorta bifurcates to form the common iliac arteries (*c.c.*), and in front of this bifurcation, from the dorsal wall of the aorta we may get a very small median sacral artery (*m.s.*), often only to be found by removing the neighbouring tissues, staining and examining them under the compound microscope. At other times I have found two, or in one case, three vessels, just visible to the naked eye, arising on either side, posteriorly, of the bifurcation, which from their distribution must represent the median sacral artery. At other times I was unable to detect any median sacral artery whatever. On its outer side each common iliac artery gives off what correspond in their distribution to the ilio-lumbar arteries (*i.l.*), and still further down there arises the circumflex (*c.*) artery, supplying the muscles of the abdominal wall, and the external circumflex (*e.c.*), a large vessel with ascending and desce ling branches supplying the muscles of the thigh. At about the middle of the thigh the external iliac or femoral artery d les into (1) the deep or profunda branch (*d.f.*), which sen a large twig, apparently the superior perforating branc n es on the outer surface of the thigh, and (2) the (*s.f.*) to the muscles

of the inner surface of the thigh and leg. The relations of these vessels in the leg and foot appear to be normal. On the inner surface of the common iliac artery and opposite to or above—but so far as my observations go, never below—the origin of the external circumflex, there is given off on each side, a very large internal iliac artery (*i.i.*). This is often as large as the external iliac artery. It sometimes arises almost dorsally from the common iliac artery, but whether so or not, always runs at first deeply and almost vertically upwards towards the dorsal surface of the animal, among the muscles of the pelvis. So sharply does it turn upwards, that, in dissecting from the ventral surface, it often appears to be absent, and is only to be seen on pushing over the main external iliac artery outwards. Often one side or the other has a much larger internal iliac artery than the opposite side, and, when this is the case, a small vessel can with care be seen connecting the two internal arteries. At first this artery gives off no branches, but then sends off a median sized one, probably the representative of the gluteal artery (*g.l.*) from its outer side. This branch appears to run almost vertically upwards to pierce the bony roof of the pelvis, and lose itself among the muscles of this dorsal region, including the "ischiotergal" slip. The internal iliac artery then passes backwards dorsally to the inner wall of the acetabulum giving rise on its outer face to two or three vessels, one of which is much larger than the others, which form by their anastomoses a plexus which is embedded in fatty tissue. From this plexus there arise two vessels running forwards and outwards to supply the muscles, ventral and lateral to the ankylosed metapophyses forming the dorsal wall of the pelvis. The largest and posterior of the three runs outwards and backwards (*s.c.*), and from its relations to the sciatic nerves, to the sacro-sciatic foramen, as well as its distribution to the muscles of the back of the thigh, probably corresponds to the sciatic artery of higher forms. The main trunk of the internal iliac artery passes directly backwards as the lateral sacral artery (*l.s.*), ventral to the transverse processes of the vertebrae, and supplies the pyriform and coccygeal muscles of this region. Just below the internal iliac artery there are given off two somewhat small vessels from the external iliac trunk, which correspond, the first with the superior vesical branch (*s.v.*) given off in Man from the

internal iliac artery, and supplying the bladder and posterior end of the ureter, while the second (*i.v.*) sends a few twigs to the base of the bladder and passes on to give off branches to the testes and to the anal glands, as also to the fatty tissue in which they are embedded. In part, therefore, it corresponds with the inferior vesical artery of higher forms.

Systemic Veins.

The three venae cavae come into contact, as in Marsupials generally, just as they are about to open separately into the right auricle, on the dorsal surface of that chamber. The left anterior vena cava approaches the heart dorsally to the arch of the aorta, while the right runs back exterior to the exit of the aorta from the left ventricle, the opening of the pulmonary venous trunk being situated in the angle formed by the approximation of the two anterior venae cavae. In one specimen, so close together were the three openings of the venae cavae, that they formed practically one aperture, subdivided by the walls of the three confluent vessels.

So far I have not with certainty found the representatives of the inferior thyroid, vertebral and internal jugular branches.

External Jugular.

The temporo-maxillary vein brings back blood from the head and face, its posterior branch entering the external jugular vein, while its anterior branch receives blood from the muscles under the chin, and also by a submental and internal maxillary, and by a facial from the face. In one specimen it appeared as though there might be an anastomosis with an anterior jugular, but if so it was very ill-defined. The main external jugular trunk begins near the angle of the jaw, by the union of the posterior auricular and posterior part of the temporo-maxillary veins. It then crosses the sterno-mastoideus very obliquely, coming to lie external to it, near the clavicle dorsal to which it crosses. Just behind the ear it is joined by the posterior external jugular, a large vessel, and posterior to this by a considerable branch from the parotid gland and by the transverse cervical vein. On its inner side it receives two distinct branches from the submaxillary

gland, these entering the external jugular vein just between the posterior external jugular and the parotid veins. Behind this, it receives the large suprascapular, bringing blood from the muscles of the shoulder and running alongside the clavicle.

Subclavian and Thoracic Veins.

The blood from the arms and axillae is returned by the representatives of the cephalic, basilic, vena comites, and subscapular veins, and, since these always seem to contain a considerable quantity of blood, the axillary vein is a large one. The blood is brought back from the thoracic walls and pectoral muscles by the usual vessels, of which the long thoracic vein is always large. The azygos veins are small, and not always easily found.

Abdominal Veins.

The posterior vena cava, anterior to its formation from the two common iliac veins, receives the lumbar veins, the two genital vessels, and two comparatively long and wide renal veins (Fig. 7, *r.v.*). Anteriorly it also receives a hepatic vein, which passes up dorsal to the digestive organs from both right and left main lobes of the liver, and enters the vena cava just as it pierces the diaphragm, a little to the right of the oesophagus. The portal vein is formed by the union of numerous branches from the mesentery of the small intestine, from the duodenal walls, pancreas and spleen, being joined by a large gastric vein close to its division into three parts one going to each of the two right lobes, and the other to the left lobe of the liver. [The bile and pancreatic ducts unite as they enter the wall of the duodenum, the duct so formed running obliquely through the wall to enter the cavity on a papilla]. The blood from the rectum is returned forwards by branches which unite to form the inferior mesenteric vein entering the hepatic portal vein. In one specimen (Fig. 7) on one side there was present, evidently as an abnormality, a second equally large and long renal vein (*R.V.*), whi[illegible] from the kidney dorsal to the ureter, instead of [illegible] does the normal vessel, and opened into the po[illegible] eighth of an inch behind the nor[illegible] (*g*) on each side leaves the te[illegible]

deferens (*v.d.*) to the root of the latter, when the blood vessel turns forwards, anastomosing by sometimes a double branch with a corresponding vein from the bladder (*v*). These two veins then run forwards along the ureter, until, when they reach the hinder edge of the kidney, they turn inwards (ventral to the abnormal renal vein when present), both entering the normal renal vein on the left side, while on the right the spermatic vein enters the right renal vein, and the vesical opens directly into the posterior vena cava. The blood from the hind limb is returned by the deep femoral and the superficial femoral veins, the former forming the external iliac vein, which receives a number of vessels from the muscles. Into it open the ilio-lumbar veins, two or three in number, the superficial and deep circumflex veins, and the long saphenous vein, all of which appear to have the same distribution and relative positions as in mammalia generally. The internal iliac veins are large and correspond very closely with the arteries in their branches and distribution, except that the well-marked vesical veins are branches of these internal iliac veins instead of belonging to the external iliac system, as do the corresponding arteries. Opening into the left internal iliac vein was occasionally a small but distinct median vessel bringing back blood from the testes and anal glands and from the surrounding fatty tissue.

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p. 539.

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1 Owen: Anatomy of Vertebrates, vol. iii., p. 540.

2 Parsons: Jour. Linn. Soc. Lond., vol. xxix., Oct., 1903, p. 64.

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deferens (*v.d.*) to the root of the latter, when the blood vessel turns forwards, anastomosing by sometimes a double branch with a corresponding vein from the bladder (*v*). These two veins then run forwards along the ureter, until, when they reach the hinder edge of the kidney, they turn inwards (ventral to the abnormal renal vein when present), both entering the normal renal vein on the left side, while on the right the spermatic vein enters the right renal vein, and the vesical opens directly into the posterior vena cava. The blood from the hind limb is returned by the deep femoral and the superficial femoral veins, the former forming the external iliac vein, which receives a number of vessels from the muscles. Into it open the ilio-lumbar veins, two or three in number, the superficial and deep circumflex veins, and the long saphenous vein, all of which appear to have the same distribution and relative positions as in mammalia generally. The internal iliac veins are large and correspond very closely with the arteries in their branches and distribution, except that the well-marked vesical veins are branches of these internal iliac veins instead of belonging to the external iliac system, as do the corresponding arteries. Opening into the left internal iliac vein was occasionally a small but distinct median vessel bringing back blood from the testes and anal glands and from the surrounding fatty tissue.

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1 Owen: Comparative Anatomy of Vertebrates, vol. iii., p. 539.
2 *Loc. cit.*, pp. 538, 540-1.

Chaeropus,[1] we find the typical marsupial arrangement of two external iliac arteries arising from the abdominal aorta, which continues posteriorly as a common iliac trunk, ending in the median sacral artery. In Didelphys virginiana,[2] and in Vesperugo noctula,[3] and Ornithorhynchus,[4] we find an arrangement somewhat similar to that of Notoryctes, the internal iliac arteries coming off from the external iliac trunks. This also is found in the higher Mammals, of which the Rabbit and also Man may be given as examples. In many Marsupials, and also in some of the higher Mammals, *e.g.*, the Rabbit, there seem to be, so far as I can find to the contrary, a common internal iliac vein receiving an internal iliac branch on the right and left, and a median sacral vein; thus in some specimens of Didelphys virginiana, McClure[5] finds this type, and also Hochstetter[6] in his series of Marsupial forms. In one species of Halmaturus, however, H. bennetti, Hochstetter finds a bifurcation of the postcaval vein into the two common iliac trunks, which are formed in turn by internal and external iliac veins, the common iliac receiving on the left side a median sacral vein. In some specimens of Didelphys virginiana,[7] McClure finds an approach to the Notoryctes type of internal iliac vein. Owen,[8] moreover, records a closely similar arrangement in the Ant-eaters and Armadilloes, and in some species of Bradypus. Each of these only differs from Notoryctes in that the latter has no median sacral vein, probably because of the small size of the tail, or the large size of the lateral sacral vessels. Except in Didelphys, in each of the Marsupial cases, so far as I can find any record, the arteries conform to the usual Marsupial type.

Conclusion.

If, with Owen,[9] we are to regard the state of development of the internal iliac vessels, especially the arteries, as a criterion

1 Parsons: Jour. Linn. Soc. Lond., vol. xxix., 1903, p. 64.
2 McClure: Anat. Anz., 18, p. 444.
3 Hochstetter: Morphol. Jabrbuch., xx. bd. 4, Heft., p. 625.
4 Owen: Comp. Anatomy of Vertebrates, vol. iii., p. 538, 540-1.
5 McClure: Anat. Anzeiger, 18, p. 444.
6 Hochstetter: Morphol. Jabrbuch, xx. bd. 4, Heft., p. 626.
7 McClure. Anat, Anzeiger, 18, Figs. 4, 8, 15, 16.
8 Owen: Comp. Anat. of Vertebrates, vol. iii., pp. 542-4.
9 *Loc. cit.*, p. 541.

of the relationship of the particular animal to Monotreme or Eutherian sub-groups, we must certainly regard Notoryctes, with its large and important internal iliac arteries, as a highly developed member of the Marsupial group, thus corroborating what has already been found in dealing with Jacobson's Organ, namely, that there is an affinity between Notoryctes and the lower forms of Eutheria, distant though that relationship may be.[2]

DESCRIPTION OF PLATES VI.-IX.

REFERENCE LETTERS.

a.	Artery.	*l.w.*	Lateral wall of Jacobson's Organ.
a.a.	Abdominal aorta.	*m.b.*	Maxillary bone.
a.c.	Alinasal cartilage.	*m.g.*	Mucous gland layer.
bl.	Bladder.	*m.s.*	Median sacral artery.
c.	Circumflex artery.	*m.t.*	Maxillo-turbinal bone.
c.c.	Common iliac artery.	*m.w.*	Mesial wall of Jacobson's Organ.
c.t.	Cavernous tissue.	*n.b.*	Nasal bones.
d.f.	Deep femoral artery.	*n.c.*	Nasal cavity.
e.c.	External circumflex artery.	*n.f.*	Nerve fibres.
e.p.	Epithelium lining palate.	*n.f.c.*	Nasal floor cartilage.
e.s.	External surface of body.	*n.l.d.*	Naso-lachrymal duct.
f.p.c.	Fibrous papillary cartilage.	*n.p.d.*	Naso-palatine duct.
i.i.	Internal iliac artery.	*n.s.b.*	Nasal septum (bone).
i.l.	Ilio-lumbar artery.	*n.s.c.*	Nasal septum (cartilage).
i.s.r.	Inferior septal ridge.	*o.J.c.*	Outer bar of Jacobson's cartilage.
i.v.	Inferior vesical artery.	*ol.ep.*	Olfactory epithelium.
g.	Spermatic vein.	*p.b.*	Premaxillary bones.
g.d.	Spermatic artery.	*p.c.*	Prenasal cartilage.
gl.	Gluteal artery.		
l.s.	Lateral sacral artery.		
l.t.	Lymphoid tissue.		

[2] Since writing the above, a memoir by Dr. B. A. Bensley has appeared in the Transactions of the Linnean Society of London (Dec., 1903), on "The Evolution of the Australian Marsupialia," which, while confirming the close relationship of Notoryctes with the Phalangeridae, does not show any very close connection with the Macropodidae, nor is it easy from it to reconcile the resemblances to the American opposums in the blood vessels, with the emphasis laid by Owen on the evidence of the internal iliac vessels.

of the inner surface of the thigh and leg. The relations of these vessels in the leg and foot appear to be normal. On the inner surface of the common iliac artery and opposite to or above—but so far as my observations go, never below—the origin of the external circumflex, there is given off on each side, a very large internal iliac artery (*i.i.*). This is often as large as the external iliac artery. It sometimes arises almost dorsally from the common iliac artery, but whether so or not, always runs at first deeply and almost vertically upwards towards the dorsal surface of the animal, among the muscles of the pelvis. So sharply does it turn upwards, that, in dissecting from the ventral surface, it often appears to be absent, and is only to be seen on pushing over the main external iliac artery outwards. Often one side or the other has a much larger internal iliac artery than the opposite side, and, when this is the case, a small vessel can with care be seen connecting the two internal arteries. At first this artery gives off no branches, but then sends off a median sized one, probably the representative of the gluteal artery (*g.l.*) from its outer side. This branch appears to run almost vertically upwards to pierce the bony roof of the pelvis, and lose itself among the muscles of this dorsal region, including the "ischiotergal" slip. The internal iliac artery then passes backwards dorsally to the inner wall of the acetabulum giving rise on its outer face to two or three vessels, one of which is much larger than the others, which form by their anastomoses a plexus which is embedded in fatty tissue. From this plexus there arise two vessels running forwards and outwards to supply the muscles, ventral and lateral to the ankylosed metapophyses forming the dorsal wall of the pelvis. The largest and posterior of the three runs outwards and backwards (*s.c.*), and from its relations to the sciatic nerves, to the sacro-sciatic foramen, as well as its distribution to the muscles of the back of the thigh, probably corresponds to the sciatic artery of higher forms. The main trunk of the internal iliac artery passes directly backwards as the lateral sacral artery (*l.s.*), ventral to the transverse processes of the vertebrae, and supplies the pyriform and coccygeal muscles of this region. Just below the internal iliac artery there are given off two somewhat small vessels from the external iliac trunk, which correspond, the first with the superior vesical branch (*s.v.*) given off in Man from the

internal iliac artery, and supplying the bladder and posterior end of the ureter, while the second (*i.v.*) sends a few twigs to the base of the bladder and passes on to give off branches to the testes and to the anal glands, as also to the fatty tissue in which they are embedded. In part, therefore, it corresponds with the inferior vesical artery of higher forms.

Systemic Veins.

The three venae cavae come into contact, as in Marsupials generally, just as they are about to open separately into the right auricle, on the dorsal surface of that chamber. The left anterior vena cava approaches the heart dorsally to the arch of the aorta, while the right runs back exterior to the exit of the aorta from the left ventricle, the opening of the pulmonary venous trunk being situated in the angle formed by the approximation of the two anterior venae cavae. In one specimen, so close together were the three openings of the venae cavae, that they formed practically one aperture, subdivided by the walls of the three confluent vessels.

So far I have not with certainty found the representatives of the inferior thyroid, vertebral and internal jugular branches.

External Jugular.

The temporo-maxillary vein brings back blood from the head and face, its posterior branch entering the external jugular vein, while its anterior branch receives blood from the muscles under the chin, and also by a submental and internal maxillary, and by a facial from the face. In one specimen it appeared as though there might be an anastomosis with an anterior jugular, but if so it was very ill-defined. The main external jugular trunk begins near the angle of the jaw, by the union of the posterior auricular and posterior part of the temporo-maxillary veins. It then crosses the sterno-mastoideus very obliquely, coming to lie external to it, near the clavicle dorsal to which it crosses. Just behind the ear it is joined by the posterior external jugular, a large vessel, and posterior to this by a considerable branch from the parotid gland and by the transverse cervical vein. On its inner side it receives two distinct branches from the submaxillary

gland, these entering the external jugular vein just between the posterior external jugular and the parotid veins. Behind this, it receives the large suprascapular, bringing blood from the muscles of the shoulder and running alongside the clavicle.

Subclavian and Thoracic Veins.

The blood from the arms and axillae is returned by the representatives of the cephalic, basilic, vena comites, and subscapular veins, and, since these always seem to contain a considerable quantity of blood, the axillary vein is a large one. The blood is brought back from the thoracic walls and pectoral muscles by the usual vessels, of which the long thoracic vein is always large. The azygos veins are small, and not always easily found.

Abdominal Veins.

The posterior vena cava, anterior to its formation from the two common iliac veins, receives the lumbar veins, the two genital vessels, and two comparatively long and wide renal veins (Fig. 7, *r.v.*). Anteriorly it also receives a hepatic vein, which passes up dorsal to the digestive organs from both right and left main lobes of the liver, and enters the vena cava just as it pierces the diaphragm, a little to the right of the oesophagus. The portal vein is formed by the union of numerous branches from the mesentery of the small intestine, from the duodenal walls, pancreas and spleen, being joined by a large gastric vein close to its division into three parts one going to each of the two right lobes, and the other to the left lobe of the liver. [The bile and pancreatic ducts unite as they enter the wall of the duodenum, the duct so formed running obliquely through the wall to enter the cavity on a papilla]. The blood from the rectum is returned forwards by branches which unite to form the inferior mesenteric vein entering the hepatic portal vein. In one specimen (Fig. 7) on one side there was present, evidently as an abnormality, a second equally large and long renal vein (*R. V.*), which emerged from the kidney dorsal to the ureter, instead of ventral to it as does the normal vessel, and opened into the post caval vein, one-eighth of an inch behind the normal vessel. The spermatic vein (*g*) on each side leaves the testis running alongside the vas

deferens (*v.d.*) to the root of the latter, when the blood vessel turns forwards, anastomosing by sometimes a double branch with a corresponding vein from the bladder (*v*). These two veins then run forwards along the ureter, until, when they reach the hinder edge of the kidney, they turn inwards (ventral to the abnormal renal vein when present), both entering the normal renal vein on the left side, while on the right the spermatic vein enters the right renal vein, and the vesical opens directly into the posterior vena cava. The blood from the hind limb is returned by the deep femoral and the superficial femoral veins, the former forming the external iliac vein, which receives a number of vessels from the muscles. Into it open the ilio-lumbar veins, two or three in number, the superficial and deep circumflex veins, and the long saphenous vein, all of which appear to have the same distribution and relative positions as in mammalia generally. The internal iliac veins are large and correspond very closely with the arteries in their branches and distribution, except that the well-marked vesical veins are branches of these internal iliac veins instead of belonging to the external iliac system, as do the corresponding arteries. Opening into the left internal iliac vein was occasionally a small but distinct median vessel bringing back blood from the testes and anal glands and from the surrounding fatty tissue.

Comparison with other Forms and Summary.

I regret that the literature obtainable here is somewhat scanty on the blood vascular system, so that I am not able to make as thorough a comparison as would otherwise be the case. The chief points of interest, however, are as follow :—

(1) The method of origin of the subclavian and carotid arteries from the aortic arch conforms in each of its two variations in Notoryctes, to one or other of the two marsupial types.[1]

(2) The blood vessels of the anterior limb are practically normal, except in size. They are larger than usual in Notoryctes, probably associated with the burrowing function of the fore-limb.

(3) In the Kangaroo and Vulpine Phalanger,[2] and also in

[1] Owen: Comparative Anatomy of Vertebrates, vol. iii., p. 539.
[2] *Loc. cit.*, pp. 538, 540-1.

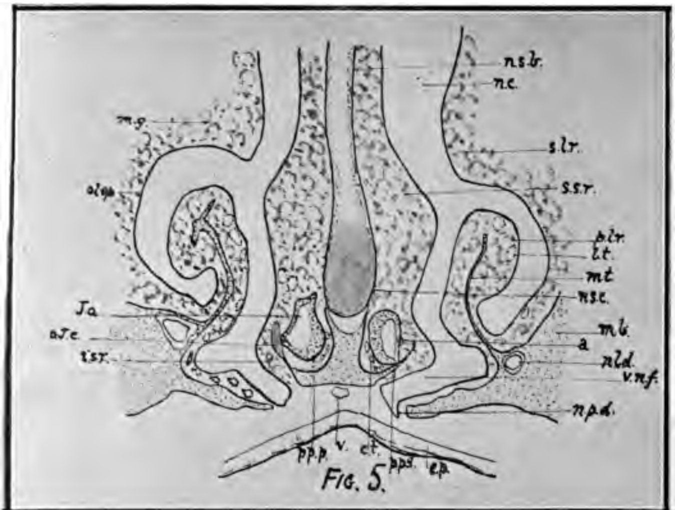
n.s.b.
n.c.
m.g.
s.l.r.
s.s.r.
ol.ep.
p.l.r.
l.t.
m.t.
n.s.c.
J.o.
o.J.c.
i.s.r.
m.b.
a
n.l.d.
v.n.f.
n.p.d.
p.p.p.
v.
c.t.
p.p.s.
e.p.

FIG. 5.

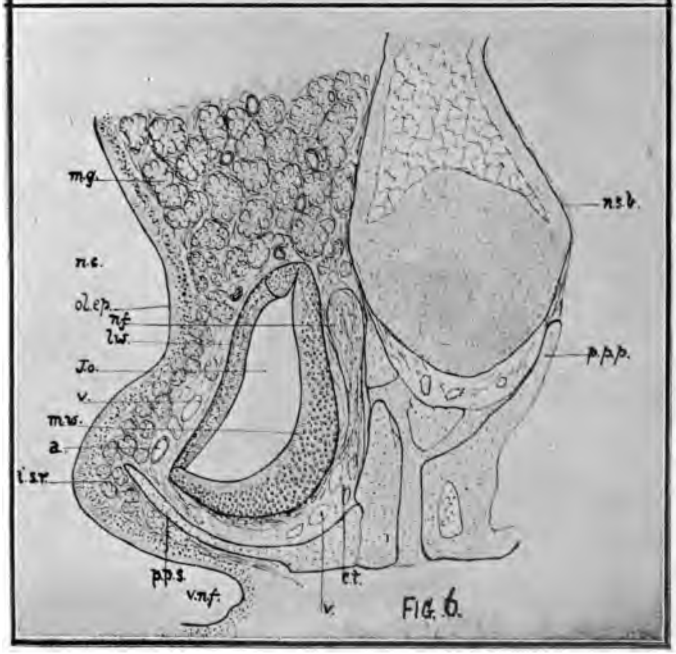
m.g.
n.s.b.
n.c.
ol.ep.
n.f.
l.w.
J.o.
v.
m.w.
a.
i.s.r.
p.p.p.
p.p.s.
v.n.f.
c.t.
v.

FIG. 6.

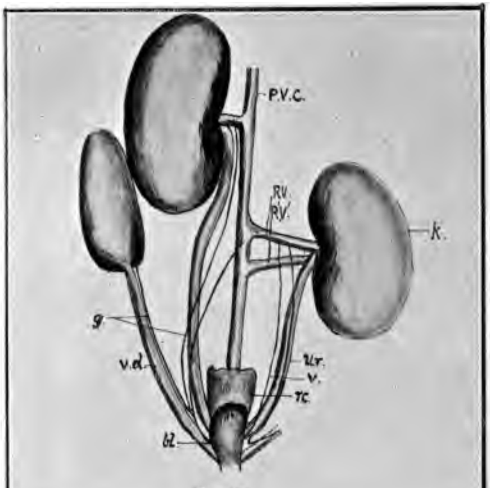

FIG. 7.

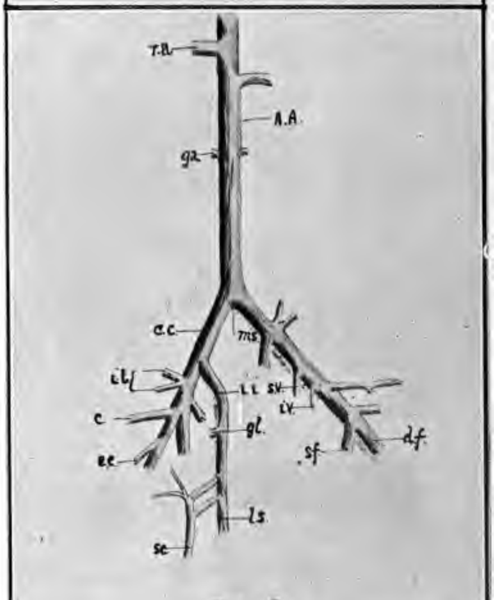

FIG. 8.

(*J.d.*) opens into the ventral nasal furrow (*v.n.f.*), in the same plane as the ventral opening of the naso-palatine canal (*n.p.d.*) into the buccal cavity. The outer bar of Jacobson's cartilage (*o.J.c.*) is here seen separated from the vertical part of the enclosing cartilage, and anterior to its union with the ventral outer edge of Jacobson's cartilage, arching in this section over Jacobson's duct. The great development of mucous glands is also evident here. Zeiss A,* oc. 2.

FIGURE 4.

Portion of transverse vertical section, three posterior to Fig. 7, showing connection of outer bar of Jacobson's cartilage (*o.J.c.*) with ventral outer edge of the now crescentic Jacobson's cartilage (*J.c.*). The opening of the naso-palatine canal (*n.p.d.*) from the ventral nasal furrow (*v.n.f.*) is clearly shown, as also the rudimentary cartilages of the nasal floor (*n.f.c.*). The naso-lachrymal duct is seen lying in a definite canal in the alveolar bone, below the maxillo-turbinal process. Zeiss A,* oc. 4.

FIGURE 5.

Section similar to last, but a little posterior to it, showing Jacobson's cartilage (*o.J.c.*) diminishing on the left, and quite replaced by a bony shelf (*p.p.s.*) from the palatine processes of the premaxillary bones (*p.p.p.*) on the right. Zeiss A,* oc. 4.

FIGURE 6.

Transverse vertical section through Jacobson's Organ (*J.O.*), showing more minutely its structure and relations. The difference between the lateral (*l.w.*) and medial walls (*m.w.*) may be noted, as also the artery (*a*) and vein (*v*) in the lateral wall, and the cavernous tissue (*c.t. and v.*) in the ventral part of the medial wall. The bundle of nerve fibres is seen descending, to be distributed to the medial wall from the main Jacobson's branch (*n.f.*) of the olfactory nerve. The mucous glands (*m.g.*) of the mucous membrane may be contrasted, in appearance and structure, with those below, which have much smaller alveoli. The bony shelf (*p.p.s.*) from the palatine processes is clearly seen. Zeiss A., oc. 4.

FIGURE 7.

Ventral view, showing kidneys, testis, and bladder, and vei associated with them. Approximately × $3\frac{1}{2}$.

FIGURE 8.

Ventral view of abdominal aorta, showing the vessels of t pelvic region. Approximately × 4.

APPENDIX.

JUNE 18TH, 1904.

A more complete paper by Professor McClure on the Anatc of the venous system of Didelphys marsupialis[1] (called in previous paper here referred to, D. virginiana) has come un my notice, and it seems desirable to make some reference t(

(1.) McClure adds yet another to the list of Marsupials which there is a common internal iliac artery—in Petrogale[1] (s as contrasted with Notoryctes (see Fig. 8). In Petrogale als(in Didelphys, there is a well marked median sacral artery sucl is not found in Notoryctes. Further, in Didelphys these arte appear to lie in general internal to the veins, sometimes do1 and sometimes ventral to them, whereas in Notoryctes arteries lie external and generally dorsal, being rarely, if e quite ventral to the veins.

With these exceptions, the division of the abdominal aort: Didelphys into two common iliac arteries, and of these external and internal branches, is very similar to the condi found in the Notoryctes, and quite unlike that found in Petro among other Marsupials.

(2.) It will be found that though some of the variations in relations of the iliac veins in Didelphys are very much like tl of Notoryctes (notably Pl. II., Fig. 8, being one variatioi McClure's Type II.), yet even here Notoryctes differs f Didelphys in the most posterior union of the common iliac form the posterior veua cava, and also in the position of

1 Amer. Jour. of Anat., vol. ii., No. 3, 1903, p. 338, fig. vi.

So that the condition of these blood vessels in tes does not by any means fit into any one of the types of ı found in Didelphys. Indeed, so far as one is justified g on an individual figure or dissection, the condition of veins, and the relation of the external iliac artery to the iliac vein, shown by McClure in Petrogale[1], is much e Notoryctes.

evident that more detailed knowledge is needed of the ı of these blood vessels in Marsupials generally before n be relied upon as a final test of affinity between

:. Jour. of Anat., vol. ii., No. 3, 1903, p. 338, fig. vi.

Art. III.—*The Relations of the Granitic and Lower Palaeozoic Rocks near Dandenong.*

By IAN M. SUTHERLAND

(Communicated by Professor J. W. Gregory, D.Sc., F.R.S.).

(With Plate X.).

[Read 12th May, 1904.]

I.—Object.

The granites of Victoria are of two ages; one granite is pre-silurian, and the other was intruded in the earlier part of the devonian age. Mr. A. W. Howitt writes:[1] "Thus, leaving out of the question those rocks which are clearly felsites, it becomes evident that there are in North Gippsland two distinct classes of granites. The older are truly granitic in character, and frequently hornblendic as well as micaceous; the younger approach nearer to the felsites, and, so far as I am aware, are not only poor in mica, but also quite without hornblende. The older granites may approximately be placed at the close of the silurian, and the younger granites in the earlier part of the devonian age. There seem therefore to be grounds for the statement that, so far as our present knowledge extends, the devonian granitic rocks of North Gippsland have a peculiar character wherever met with; but in this it is necessary to guard strongly against the supposition that no true granites may have been formed in that age."

In memoirs of the Geological Survey of Victoria, in an appendix to the Report on the Chiltern Goldfields, by Stanley B. Hunter, page 42, Professor Gregory writes: "Mr. Howitt long since suggested that the granitic rocks of Victoria belong to two distinct groups. Those of one group were intrusive in devonian times. The earlier group was pre-silurian. It has been the custom to regard the great majority of the Victorian granitic rocks as belonging to the devonian group."

1 Report of Progress of the Geological Survey of Victoria, 1877. Notes on the Geology of Part of the Mitchell River Division of the Mining District of Gippsland, p. 121.

The age of the granite at Walhalla has an important bearing on the geology of the goldfield of that district, but no fully satisfactory evidence of its age has hitherto been got near there. The granite is marked on the Geological Sketch Map of Victoria as extending almost continuously from Dandenong to Mount Baw Baw and Walhalla, and therefore its age at these three places is probably the same.

As the two groups of granites are not distinguished in the geological maps of Victoria, at the suggestion of Professor Gregory, I have examined the granite near Dandenong to try to determine its age relative to the lower palaeozoic beds.[1]

II.—Topography.

Dandenong is eighteen miles south-east of Melbourne, on the creek of the same name, which flows from the swampy land to the north-east of the Dandenong ranges. The township is about 69 feet above sea level, on slightly undulating country, to the north-east of which rise the "Dandenong Ranges"; but as these hills are isolated or connected by very low saddles, a better name would be the Dandenong Hills. Near Dandenong there are three types of rocks :—

1. Granite, forming the picturesque foot hills of the proposed National Park, in the old Police Paddocks, and the hills to the east and north-east.
2. Dacites, similar to those of Mount Dandenong, occurring near Ferntree Gully.
3. Lower palaeozoic rocks, on the flanks of the granite, and forming the low, undulating country towards Oakleigh.

III.—Literature.

There is not much literature on the geology of Dandenong district.

The earliest is a report by the late A. R. C. Selwyn on a geological map of the country between Port Phillip Bay and

1 In the absence of fossil evidence there is no certainty whether the rocks be ordovician or silurian, but the discovery, by Mr. Ferguson, of ordovician fossils in the Mornington peninsula suggests the possibility that the lower palaeozoic rocks in contact with the granites at Dandenong are also ordovician. In that case the Dandenong-Baw Baw massif may be pre-silurian though post-ordovician.

Westernport.[1] The Dandenong Creek forms part of the easter boundary of Selwyn's map, and as all the granite, except on very small outcrop, is on the east side of the creek, the onl mention of the Dandenong plutonic rocks is: "These two rocks (feldspar-porphyry and syenite) "occur as narrow dykes cuttin through and upheaving the older palaeozoic rocks, the forme being on the south banks of the Yarra, and to the north of Me bourne, and the latter near Dandenong." The land to the sout of Dandenong is described in the map as palaeozoic sandstone shales, clay-slates, etc. A dyke of "sienite" is shown crossin the Dandenong creek, near Dandenong township.

In the Report of the Geological Surveyor on the Geologica Structure of Victoria, 1855-56, Sec. 3, page 17, Selwyn, in hi description of the plutonic rocks south of the Yarra and ea of the Dandenong Creek, writes: "They have upheaved an metamorphosed the palaeozoic strata on their flanks, and ha therefore been intruded since the deposition of the latte Whether the granite and porphyries are of different periods, only accidental modifications in mineral character of the sa mass is uncertain. They often appear to pass into each oth but small isolated patches of the porphyry, as well as branch from the mass, are found penetrating the granite, which is n found similarly intruding in the porphyry; and we might the fore imagine the porphyry to have been erupted at a peri subsequent to the formation of the granite. "The granite ne Dandenong is not described particularly in "Geology a Physical Geography of Victoria," by Reginald A. F. Murra On page 27 he writes: "Among the areas represented as 'tra on the Geological Sketch Map, the rocks in three, namely, tho of Mount Macedon, the Dandenong Ranges and Mount Julie besides others of minor extent, appear to be intimately associate with the ordinary granites, though the true relations of the rock have not yet been properly investigated." On page 28, M Murray mentions that specimens of "ternary granite" an "syenitic prophyry" from near Dandenong, and of "micaceou felspar trap," "felspar porphyry," and "syenitic felspa porphyry" from the Dandenong Ranges, are described in M

1 Victoria. Votes and Proceedings, 1854-55, vol. i., pt. ii., p. 976.

Selwyn's catalogue. In a paper published in the Proceedings of the Royal Society of Victoria, vol. xiv., pt. ii., page 211, Professor Gregory writes: "Mr. Ferguson has stated that there is a gradual change from the 'granites' to the Dandenong 'traps'; but I have failed to find evidence of this, and Mr. T. S. Hart, who examined the sections on the Gembrook railway, tells me that wherever the two rocks could be seen together they were both greatly decomposed. He says there was no sign of a passage between the two rocks. This evidence is consistent with the view that the diorites and the dacites belong to different dates, and had independent origins." In a footnote Professor Gregory adds: "Since the paper was read I have examined the sections in question, and agree with Mr. Hart's conclusions." In the same paper (page 201) are given analyses of two porphyrites and a granodiorite from two miles north of Dandenong township, and a Dandenong dacite; the analyses were made by the then Government Metallurgist, Mr. H. C. Jenkins, A.R.S.M.

IV.—Geological Structure.

Near Oakleigh the lower palaeozoic rock is a soft, yellow mudstone, containing no fossils, and having a dip of about 18° W. The beds continue to the east without any change, except that of dip, as far as the Stud Road running north from Dandenong. On the west of this road the dip is constant for about three miles, and is 35° E.; it does not correspond to the surface formation, which seems to be due to erosion. About four miles north of Dandenong the Lysterfield Road, running east and west, crosses the Stud Road. On the south side of this crossing, for about a mile along the Stud Road, the lower palaeozoic rocks are exposed by road cuttings. The rock has the same appearance as that near Oakleigh, and the dip varies from 26° to 36° in directions between N. and and E.; the dip of the beds in these cuttings, and in all the other places where it can be seen, is nearly always towards the granite area and never away from it. The dip is very variable, and about a mile south of the Lysterfield Road there are some faults exposed by a shallow road cutting. On the east side of the Stud Road, on the Lysterfield Road, are a few cuttings showing lower palaeo-

zoic rock. Near the Stud Road the rock is very much broken, and the bedding is indistinguishable, but the rock is not otherwise altered. The next cutting is about two miles to the east of the Stud Road, where the Lysterfield Road crosses the foot of a hill; the rock shown has lost all sign of stratification, is harder than the unaltered rock, and is coloured red with iron. At the summit of the hill small pieces of indurated rock are scattered about, some of them showing traces of stratification. A series of hills of similar formation lies to the south-west of this hill, towards the Lower Reservoir. In a quarry for road-making, near the foot of one of the hills, the altered rock is very hard, and has no apparent stratification. In one part of the face of the quarry there is some very decomposed rock, containing a good deal of mica; it underlies the altered rock, and may be a granitic dyke. The surface of some of the altered rock is encrusted with secondary mica.

To the east and south-east of these hills there is a great number of smaller hills showing granite bosses near their summits, but I could find no other rock except at two places; the first is about half-a-mile south of the Lysterfield Road, and is marked (12) on the sketch map. At this point, near the foot of a hill, there is an outcrop of intensely altered stratified rock containing white mica, and bedded vertically; it has a strike N.N.E., or at right angles to the slope of the hill. The outcrop of granite begins about ten yards higher up the hill, but the actual contact is hidden by soil. The second place where other rock besides granite is exposed is marked (11) on the sketch map. A hill, showing large outcrops of granite, is crossed by a dyke about six feet wide, and exposed for about 100 yards; the granite can be seen on both sides, but the line of contact is hidden by soil. In structure the dyke rock is much finer grained than the granite, and was therefore probably formed under smaller pressure and later than the granite. Further south, on Bald Hill, loose pieces of rock, similar in appearance to that of the dyke, are found above the granite in a cutting, but no dyke can be seen.

V.—Conclusions.

As the granite is approached, the alteration in the ordovician or silurian rocks is so marked that there can be no doubt that the granite is post-ordovician. Most of the stratified rock near Dandenong is hidden by a thick layer of loam and clay, so that the bedding can only be seen in a few road-cuttings and quarries. As stated above, the lower palaeozoic beds wherever exposed are found in almost all cases to dip away from the granite area. This formation seems to be common in Victoria, and Mr. R. A. F. Murray in his Geology and Physical Geography of Victoria, page 24, writes: "Another marked feature is that the granite intrusions do not appear to be connected with the folding process to which the silurian rocks have been subjected, and to which is due the normal high rate of inclination of their layers. That process would appear to have taken place prior to the invasion of the sedimentary strata by igneous masses, as we find in many cases that the strike of silurian strata abuts directly on the granite, and in others that the dip of the strata is against, instead of with, the surface slope of the granite. Evidences of the intrusive character of the granite to a certain extent are, however, visible in many places, in the locally contorted and crumpled state of the silurian strata, near their contact with the former."

Mr. Murray then goes on to infer, from the description given by A. R. C. Selwyn, of the country east of the Snowy River, that much of the granite there was formed by the fusion and recrystallization of the silurian rocks. The granite near Dandenong does not seem to have been formed in this way as there is no intermediate rock between the granite and altered stratified rock.

There is no evidence to show that the dacite further north, near Ferntree Gully, is contemporaneous with the granite. Since dykes have been found connected with the granite, but none with the dacite, the latter is probably the younger. Therefore the granite was formed after the ordovician period, but before the dacite.

APPENDIX.

Note on the Microscopic Structure of Some Rocks from Dandenong,

BY PROFESSOR J. W. GREGORY, D.Sc., F.R.S.

In connection with Mr. Sutherland's paper on the lower palaeozoic and granite rocks of Dandenong, I have given a few of the rocks a microscopic examination. One of the lower palaeozoic rocks from allotment 61, Narre Warren, collected by the contact, proves, on microscopic examination, to have been altered into a very fine grained biotite hornstone; it closely resembles some of the ordinary typical rocks formed by contact metamorphism around our granitic masses. The ordinary granitic rock of the district is connected with a series of dykes the examination of which was of interest, owing to the possibility of some of them having been connected with the Dandenong dacites. The dykes examined, however, have no connection with that series, and may be all derived from the much older grano-diorite massif.

The dykes, of which the best occur in the Police Paddock and some adjacent allotments, belong to two groups. The first is diorite-porphyry (No. 11), which is composed of phenocrysts of pale, partially leached, hornblende, and of andesine in a coarsely granular holocrystalline base. The second series of dykes is better described as quartz-biotite-porphyrite. Biotite is abundant, but has now been mainly altered into chlorite, the large crystals containing granules of epidote, surrounded by the green chlorite. There are abundant corroded and embayed phenocrysts of quartz, and also of plagioclase. These phenocrysts are widely scattered in a very fine-grained felsitic base, which was, no doubt, originally glassy. In some cases the felspars have undergone considerable decomposition, and the dull, dusty crystals, under polarised light, are lightened up by the bright granules of zoisite.

The following analyses of these rocks may be conveniently repeated[1]:—

1 Gregory, J. W.: The Geology of Mount Macedon Victoria. Proc. Roy. Soc. Vict., vol. xiv., n.s., 1902, p. 201.


ALLUVIUM.
SILURIAN.
ALTERED SILURIAN
GRANITE.
POLICE RESERVE
ROAD
DANDENONG C

TWO MILES NORTH OF DANDENONG TOWNSHIP.

	Porphyrite.	Porphyrite.	Grano-diorite.
SiO_2	64.0	65.05	63.38
Al_2O_3	19.11	10.04	17.36
FeO	2.80	5.14	1.98
Fe_2O_3	2.22	8.47	1.61
FeS	1.58	1.35	3.38
CaO	5.13	4.80	4.18
MgO	2.17	trace	1.80
K_2O	.14	.02	.31
Na_2O	1.12	3.39	4.07
H_2O	1.01	.56	.54
CO_2	1.71	1.53	1.13
	101.19	100.35	99.74

he analyses of the dykes show by the excess of lime and nesia over the alkalies, that the plagioclase belongs rather he basic series; and the large amount of lime and practical nce of potash from the plutonic rock, taken in conjunction ı the high silica percentage, shows that it is to be regarded granodiorite rather than a granite.

Art. IV.—*The Antiquity of Man in Victoria.*

By J. W. GREGORY, D.Sc., F.R.S.

(Professor of Geology, at the University, Melbourne).

Contents.

I.—Introduction.

At the end of a paper on the geology of Mount Macedon, read before this Society in 1901, I expressed the view, which seemed to me the general belief in Victoria, that man witnessed the last of our volcanic eruptions. "It is not improbable," the paper concluded, "that Mount Macedon is one of the volcanic piles that mark the beginning of the great period of volcanic activity, of which the last eruptions built up still-existing craters, and are recorded in the legends of the Victorian aborigines."[1] I had not then had time to consider the evidence critically; but it seemed to justify the current opinion, that the human occupation of

1 The Geology of Mount Macedon, Victoria. Proc. Roy. Soc. Vict., vol. xiv., n.s., 1902, p. 214.

Victoria dated from the volcanic period. The evidence quoted in support of this belief was the occurrence of human implements below the lavas, and upon the existence of aboriginal traditions of the eruptions. Since then I have had time to go into the evidence, and am forced to abandon the opinion then accepted. Some of the grounds for this change of view are briefly stated in the Geography of Victoria (p. 51), but, as the subject is of much interest, the arguments may be conveniently restated at greater length, in the hope of thereby bringing forth any convincing evidence to the contrary that may be available.

II.—Reported Human Relics of the Victorian Volcanic Period.

The most reliable evidence of the existence of man in Victoria, at the time of the last volcanic eruptions, would be the occurrence of stone implements or of human remains in beds interstratified with or below the volcanic rocks. Evidence of this nature has been adduced; but its reliability is doubtful. Some of it may be dismissed very summarily. Thus, an aboriginal canoe is said to have been found in one of the deep leads under the basalts of Mount Tabletop in Dargo. Mr. Stanley Hunter, of the Geological Survey, informs me that this canoe was an ironstone concretion; its shape, from his description, was that of the bow of an English canoe (of the Rob Roy type), and did not resemble the aboriginal Victorian canoe. This concretionary canoe has found its way into our literature. Further evidence that may be as readily disposed of is that of the reported aboriginal camp fires under the Melbourne lava flows, at the Corporation Quarries in Collingwood. On enquiry at the quarry, I was told that the reports of the aboriginal fire-places were based upon a practical joke. Whether this be so or not, the evidence has not been formerly recorded or described, and is at present merely hearsay.

1. *The Buninyong Bone.*—The most definite evidence in favour of the existence of man, earlier than some of the basaltic lavas, is a cut fragment of bone, found near Ballarat, in a bed of silt, which lies beneath a sheet of basalt, formed as one of the south-western flows from Mount Buninyong. The specimen belongs to the Museum of the Ballarat School of Mines. The

geological situation in which this bone was found has been carefully described by Mr. T. S. Hart,[1] of the Ballarat School of Mines, and the bone by Mr. de Vis.[2] Its interest, as Mr. de Vis states, is due to the fact that "on its posterior face the rib had been half sundered by a cut through its dense cortex."

The bone is a fragment of the rib of some giant marsupial, and corresponds precisely, according to de Vis, with *Nototherium mitchelli.* The fragment is 6 inches long. Part of the edge has been split off, and the bone has been thus reduced in width to $1\frac{2}{3}$ inches. The bone is roughly fractured at one end and along one side. The face has been flattened in two places by abrasion, and at one end there is a long, sharp straight cut. Mr. de Vis considers the possibility of this cut having been made by the teeth of some animal; but the only animal that, as he says, could even excite suspicion, is the marsupial Lion, *Thylacoleo carnifex.* There is no reason to consider that this animal could have made such an incision; the bone does not appear to have been gnawed, and those who have recently examined the bone generally agree that the cut must have been made by a sharp metal implement. The smooth surface was not likely to have been made by rubbing down, because the opposite side of the bone projects with a jagged broken edge, which would have been worn down at the same time. The bone has been pyritized; therefore, to preserve it from decay, it has been sized and varnished, so that the freshness of the cut cannot now be determined.

That the bone originally came from the swamp deposit below the lava flow seems to me almost certain, for the head of the same rib was found accompanying it. So far as I know, there is no deposit of fossil marsupial bones near Buninyong, whence the bones could have come. There is no special reason to regard the specimen as having originated as a joke or fraud. It was handed by the workmen who found it, to the manager, Mr. Kent, who gave it to one of the directors of the mine, Mr. W. R. Vale, who in turn handed it to Mr. Hart. Mr. Kent has made a statutory declaration that he received the bone, covered with dirt, with

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1 Hart, T. S.: "The Bone Clay and Associated Basalts at the Great Buninyong Estate Mine." Proc. Roy. Soc. Vict., vol. xii., n.s., Melbourne, 1899, pp. 74-80.

2 de Vis, C. W.: "Remarks on a Fossil Implement and Bones of an Extinct Kangaroo." Proc. Roy. Soc. Vict., vol xii., n.s., Melbourne, 1899, pp. 81-90, pl. vii.

others, found at the same place, from the workmen; and that he handed it in that condition to Mr. Vale. Mr. de Vis seems to have been very suspicious of the specimen at first, when he found that with a penknife, from a similar piece of Nototherium rib, he could carve a very fair imitation of the fossil. But his suspicions were overcome by the assurances that he received, and he concluded that the bone received its present shape from the hands of man, before it was buried 238 feet below the present surface of the ground.

If this bone had been cut to its present form by man, before it was dropped in the swamp deposit, then man must have been contemporary with some of the Victorian volcanic eruptions. The geological evidence is conclusive that the swamp deposits, in which the bone was buried, were earlier than the overlying basalt flow from Mount Buninyong. The cut on this bone is regarded as of human origin by, so far as I know, all those who have carefully examined it, and there is no special reason to doubt the genuineness of the discovery, or the good faith of the men who found it. Nevertheless, faith in this implement is not so general as I at first believed. It has recently been carefully examined or re-examined by Professor Spencer, Mr. Kenyon, and Mr. T. S. Hall. They allow me to say that they discredit it as proof of the great antiquity of man in Victoria. Mr. de Vis tells me in a letter that "with regard to the scraper, when I wrote 'if an implement' I did not intend to imply that it had not been fashioned by the hand of man, for this I believe it to have been (so does Professor Yashenko to whom I showed a cast), but that there lingers in my mind some doubt, whether it was formed before burial or after resurrection. I confess, the doubt arises purely from negative evidence, the absence of signs elsewhere of man in competition with the great marsupials."

Mr. Howitt tells me that "I do not rely upon the discovery of tho bones in the Buninyong Mine or the apparent artificial cuts in them;" and reference to his address to the Australasian Association for the Advancement of Science, in 1898, shows that he even then regarded the evidence of the specimen with considerable suspicion.

I have had the opportunity of showing the specimen to Mr. A. S. Kenyon, whose experience of the stone and bone imple-

ments of the Victorian aborigines is probably unequalled. He tells me that the Buninyong bone is unlike any Victorian stone or bone implement that he has seen, and that he thinks it must have been cut by a sharper implement than any which the aborigines had. He is emphatic that the work upon their bone implements was quite different in character.

The fact that the head of the same rib was found in the same group of bones tells against the bone having been fashioned as an implement. It is possible that an aboriginee may have started to make a bone scraper and not have finished it, and have knocked off the head of the rib at the place where he left it. But it is more probable that the bone would have been cut before being carried into the swamp, and the broken pieces would not have been found lying beside it, unless it had been fractured after burial.

The main evidence against this bone having been cut by aborigines is that the workmanship is not of the type they used. No known Victorian aboriginal bone has been found with such a cut. The jagged edge projecting beside the smooth cut surface would have rendered it useless as a scraper; but even if the specimen had been cut as such, it is improbable that the head of the rib should have been found beside it. Hence the general evidence forces me to conclude that we cannot accept the high antiquity of man in Victoria on the evidence of this bone alone.

It is also significant that nothing else that could be regarded as a trace of man was found in the same bed. There were no worked stone flakes, and in no other Victorian locality, where the remains of giant marsupials occur, is there evidence of the contemporary existence of man. It may be claimed that the existence of one definite specimen is sufficient to settle the question. But bones can be cut by carnivorous mammals, such as the *Thylacoleo carnifex* and the dingo, which both lived in Victoria at the same time as the giant marsupials. I fully agree, however, with Mr. de Vis that this cut was not made by the teeth of any animal, as it appears to be due to a sharp cutting tool. I am not prepared to offer any positive opinion as to how this bone was cut, any more than I am prepared to explain how the Calaveras skull was buried in California, or what particular mistake led to the genuine belief, in the eighteenth century, that a whaler, Captain Johnson, had got within two degrees of the North Pole.

It seems to me possible that the specimen is the result of an accident, for the shovel of one of the workmen might have cut into the bone and broken it while it was lying in the silt; the shovel, at the same time, may have driven mud into the cut surface, and thus have hidden its recent formation.

In dealing with fossil traces of man, the evidence of a single specimen, which was not collected *in situ* by a collector of known trustworthiness, must always be received with caution. The chance of genuine mistake and of practical joke must not be forgotten. The literature of the antiquity of man contains many warnings against founding important conclusions upon single specimens, brought into court by men who were not trained geologists. And in this case there is the additional need for caution in that the bone does not resemble those of our aborigines, and that it would appear to prove not only a great antiquity for man in Victoria, but also that these early men were provided with metal tools.

Accidents are apt to occur in the burial of human implements, and casual specimens must be regarded with reserve. There is, for example, the case of the discovery of some recent keys on a beach near Geelong under fifteen feet of drift. This discovery was reported by the first Lieutenant-Governor of Victoria, C. J. Latrobe,[1] and considered by him to prove a recent elevation of the sea in that district. Rawlinson discussed the evidence, and concluded that the keys had been left by buccaneers two or three centuries before.[2]

2. *The Maryborough Implement.*—Another supposed ancient implement associated with our volcanic rocks was found at Maryborough in 1855, at the depth of four feet from the surface. The specimen was found in the gravels of a small tributary, and not below the basalts of the main lead. Mr. Stanley Hunter, of the Mines Department, was sent, at the request of Mr. Howitt, to examine the locality; and on asking Mr. Hunter for information, I find he attaches no reliance to the evidence. The specimen at best only came from a shallow deposit, and the alleged implement may have fallen into a natural hollow or wombat hole.

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1 Rawlinson, T.: "Notes on the Discovery of some Keys in the Shore Formation of Corio Bay, near Geelong." Proc. Roy. Soc. Vict., vol. xii., Melbourne, 1876, pp. 33-43.

2 Rawlinson: *Op. cit.*, p. 40.

If we are to carry man back to the antiquity of any deposit, in which one of his implements has been found, we might claim that he dates, in Victoria, from Miocene times. During one of the excursions of the Geology School of the University, Mr. D. J. Mahony found a bone implement in the Middle Kainozoic marls at Waurn Ponds. I was present when the specimen was found, and it was unquestionably obtained *in situ* from the marl, and was unquestionably an aboriginal implement. Subsequently, however, I found that the specimen was of the type known as a bone pointer. Such implements were used to injure an enemy by witchcraft. A sharply pointed piece of human bone was pointed at an enemy, while various incantations were repeated; the bone was then buried in the ground, whence, according to the aboriginal belief, it would make its way into the body of the person at whom it had been pointed. When I found out the nature of this implement its occurrence in the marls was easily explained. The tribe which lived at Waurn Ponds must have practised this rite; and the bone was pushed into the ground at a point where the marls were exposed on the surface; and thus it was found in a very old deposit which showed no obvious sign of disturbance.

III.—The Distribution of Aboriginal Remains in Superficial Deposits.

The Buninyong specimen is unique, as it is the only one that is connected with our volcanic rocks, although aboriginal implements have been found in Victorian gravels of some antiquity. But, their evidence is equally unsatisfactory. Our gravels have been turned over so often, that specimens lying on the surface may easily have been buried in old gravels and then re-discovered. There are, however, no cases of undoubted implements found in ancient gravels, which require explanation by this hypothesis. The Ballarat implement, quoted by Dicker's Mining Record,[1] is the best I have come across, which even suggests the occurrence of man in the early Pleistocene gravels. This specimen was a stone basalt axe, 5 lbs. in weight, 8 inches long, and 4 inches in greatest thickness; it is

1 Ancient Mining Tools: Singular Discovery of a Stone Implement or Weapon at Ballarat. Dicker's Min. Rec., vol. iii., 1864, pp. 120-121.

grooved, showing that it was mounted in a handle. It was found in gravel at Ballarat when digging a garden trench, at the depth of twenty-two inches from the surface. There is nothing in this case to prove any great antiquity for the maker of this axe.

The old surfaces on the coastal dunes offer perhaps, the best chance of definite evidence as to the antiquity of man in Victoria. These dunes have been accumulating since early Pleistocene, or perhaps even Pliocene, times; the aborigines frequented these dunes, as they provided excellent camping grounds, and the shores yielded an abundant supply of shell fish and other food. The old camps on the dunes, when exposed by the wind, afford the richest collecting grounds of Victorian aboriginal remains. Stone flakes, ovens and kitchen middens are abundant and conspicuous. But the lower dune surfaces, some of which, judging from general geographical considerations, are probably only 300 or 400 years old, are quite bare of human remains. We find aboriginal kitchen middens extending for miles along the cliffs; but they are all superficial. The older dune surfaces would no doubt show similar kitchen middens had the natives lived on them. But they show no trace of man.

There are records of human specimens having been found in the sand dunes; as by Wilkinson in 1864 near Cape Otway, and Mr. Robert Etheridge, junr., who subsequently obtained a bone spike at the same locality. Messrs. David and Etheridge record both discoveries, and remark that the "remains of this nature, lying as they did beneath sand dunes at least 200 feet high, must have been of great antiquity."[1] This evidence is weighty; but it must be remembered that the record of Wilkinson's discovery appears to rest on hearsay evidence, and Etheridge's original description of his discovery is less emphatic. He remarks that his specimen was found in "a mixture of beach material, pebbles, humus, and broken shells, resting on the carbonaceous sandstone forming the high cliffs of the Cape, and *apparently* intermediate between it and the outlying dunes."[2] Considering

1 David and Etheridge: "Report on the Discovery of Human Remains in the Sand and Pumice bed at Long Bay, near Botany." Records Geol. Survey, N.S.W., 1889, vol. i., pt. I., p. 15.

2 Etheridge, R., junr.: "Observations on Sand-dunes of the Coast of Victoria." Proc. Roy. Soc. Vict., vol. xii., 1876, p. 4.

the rapidity with which sand dunes travel, it appears quite possible that these implements were buried by an advancing dune, and need not imply any vast antiquity. It is probable that the layer with the broken shells was only the surface layer on the dunes, resting on the underlying sandstones on the edge of the dune.

Further striking negative evidence is given by the bone beds beside Lake Kolungulac, and elsewhere in the Hampden basin; they contain bones of the giant marsupials, and if the aborigines then lived in Victoria, they would surely have gone to those localities to obtain food. So far no worked flakes have been found in association with these bones, and none of the bones show any signs of having been cut or broken by the aborigines.

Again, the dunes beside the lakes on the western plains have heaps of kitchen midden material. They only occur on the surface. Sections have been cut in all directions through the dunes, but none of these conspicuous hummocks of rubbish have been found at any depth that would imply any considerable antiquity. The quarries at Mount William, near Lancefield, worked by the aborigines for the stone used for their greenstone axes, are all small and shallow, and no great amount of stone has been removed from them.

Negative evidence has, of course, to be accepted with reserve, but it is unusually weighty in regard to the age of the Australian aborigines. The stone flakes, which they used, are almost indestructible; and they are scattered with extravagant untidiness about the aboriginal camps, where chipped stones can be collected by the bushel. The sites of the recent aboriginal camps in the Lake Eyre district, and of the earlier aborigines in Victoria, are marked by large quantities of these implements. Polished aboriginal axes are scarcer, but they also have been found widely scattered over the surface of Victoria. Accordingly, if aborigines lived long ago in Victoria, we ought to expect an abundance of their stone implements in the beds then being deposited. Excellent sites for former camps can be easily found. The "false bottoms" or "cement floors," which occur in our alluvial deposits, would have formed admirable camping grounds, and hundreds of acres of these floors have been cleared by mining operations, and the surfaces searched by our keen,

sharp-sighted miners. In no country in the world have the gravels been searched so thoroughly, or are there such extensive exposures still open, as in Victoria.[1] The gravels, moreover, have been searched by highly intelligent observers, many of whom were keenly interested in the aborigines, and on the lookout for any traces of them. It is almost inconceivable, if man had been living at the time when these gravels were being laid down, that worked flakes and stone and bone implements should not have been discovered.

The absence of traces of aboriginal man, except from the most superficial and recent deposits, is admitted by all Victorian collectors. This fact is emphatically asserted by Brough Smyth. He concludes: "It is remarkable that no stone hatchet, chip of basalt, or stone knife has been found anywhere in Victoria, except on the surface of the ground or a few inches beneath the surface. It is true that fragments of tomahawks and bone-needles have been dug out of Mirrn-yong heaps on the sea-coast, covered wholly or partially by blown sand; but, though some hundreds of square miles of alluvial have been turned over in mining for gold, not a trace of any work of human hands has been discovered. Some of the drifts are not more than three or four feet in thickness (from the surface to the bed-rock), and the fact that no aboriginal implement, no bone belonging to man, has been met with is startling and perplexing."[2] This fact is still more striking now than it was in 1876, for it has been confirmed by subsequent work. Thus Mr. W. H. Ferguson, an enthusiastic and thoroughly reliable collector of aboriginal flakes, states that the deepest level at which he has found any has been the depth of 12 feet, in some of the Murray silts, near Talgarno. These silts accumulate very rapidly, and the banks of the Murray were probably the first Victorian locality at which the aborigines camped. There is nothing in these 12 feet of silt indicating any considerable antiquity. Mr. Kenyon, the most experienced Victorian collector of aboriginal implements, tells me he has never found them except close to the surface. He has

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1 The parts of Victoria which should be excepted from this statement are the province of Croajingolong in the extreme east, and parts of the Mallee country in the extreme north-west.

2 Brough Smyth.

indeed found skeletons in three distinct layers in the shifting sand dunes of the Lower Loddon; but these dunes accumulate so rapidly, that the deepest skeleton need not be more than a few centuries old.

The lack of aboriginal implements from our gravels, dunes, river silts, and volcanic rocks gives very weighty evidence that man was not present in Victoria during their formation.

IV.—Supposed Ancient Human Impressions in "Warrnambool Sandstone."

Considerable attention has been recently called to a slab of dune limestone containing some well-marked impressions, now in the Warrnambool Museum. The rock is generally known by its local name of "Warrnambool Sandstone." It was clearly formed in dunes, composed of shell-sand and foraminifera, the grains of which have been cemented into a coherent rock. The face of the slab represents the false-bedded surface on the slope of the dune. On the slab there are, side by side, two broad, smooth depressions. One margin of each is preserved, and is a regular, open curve; the two depressions are separated by a ridge of $\frac{7}{8}$ of an inch in width. In front of one of the depressions are two deep imprints, as if made by a pair of feet.

The following interpretation of the specimen is attached to it in the Warrnambool Museum:—"The imprints upon it are those of a woman and a man who, during the geologic period, at the time when the slab was loose sand forming part of the ancient hummock or sand dune similar to those found around our coast at the present, were sitting side by side at its foot. Two footprints on the left side, longer and wider, evidently those of the man, were taken away and built into the walls of the Town Hall."

The label gives not an unnatural explanation of the impressions on this slab. The human origin of the imprints has been affirmed by Mr. Graham Officer,[1] who first described them; by Archibald,[2]

1 Officer, C. G. W.: "The Discovery of Supposed Human Footprints on Aeolian Rock at Warrnambool." Vict. Nat., vol. ix., 1892, pp. 32-39.

2 Archibald: "The Discovery of the most Ancient or Tertiary Men in Australia;" Science of Man, vol. i., No. 2, n.s., pp. 40-41, Sydney, 21st March, 1898. See also "Further evidence to establish discoveries in Warrnambool quarries;" *Ibid.*, vol. i., No. 4, pp. 86-7, Sydney, 21st May, 1898. "The Palaeolithic Men in Tasmania and Australia;" *Ibid.*, vol. ii., No. 2, n.s., p. 30, Sydney, 21st March, 1899. "The Relics of Primitive Men found in Australia;" *Ibid.*, vol. ii., No. 2, n.s., pp. 32-33, Sydney, 21st March, 1899.

formerly curator of the Warrnambool Museum; his successor, Mr. Jas. McDowell;[1] and Mr. A. C. MacDonald.[2] This hypothesis is discredited by Messrs. T. S. Hall, W. Howchin, E. F. Pittman, R. Etheridge, G. B. Pritchard, T. S. Hart, J. Dennant, J. Stirling, and A. W. Howitt,[3] some of whom, however, have not seen the specimen. If the impressions are aboriginal footprints then man must have been in the Warrnambool district a considerable period ago. According to E. D. Cooke, in a handbill, printed at Essendon, 21st January, 1892, this specimen proves man to be of Pliocene age in Australia. There is no need to go as far back as that, for there is no evidence that the rock is of Pliocene age.[4] Only one fossil bone, as far as I know, has been found in this formation, and that gives no evidence that the rock was deposited at the time of the giant marsupials.

The Warrnambool dune limestones are some 70 feet thick; and they must have taken centuries, probably many centuries, to accumulate. The slab with the impressions was found in Kellas' quarry, in section 24 of allotment 28, in the Borough of Warrnambool. This position is in the heart of the dune limestones, which extend for a little more than half a mile both to the south and to the north, as well as for a considerable distance east and west. The slab was dug up at a depth of 54 feet from the surface, and therefore comes from the lower part of the limestone series. The position of the quarry renders it improbable that this slab could have been formed at the close of the dune series, on the flank of the main mass of the formation. The rock was found on the 5th December, 1890, and was promptly given to the Museum. Unfortunately it is an especially friable variety of "Warrnambool sandstone," and all the original surface of the imprints has crumbled away. Mr. McDowell, the curator of the Museum, says that he was told that the imprints were lined by a

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1 McDowell, James: "Footmarks in Rocks." *Ibid.*, vol. ii., No. 2, n.s., p. 216, Sydney, 21st December, 1899.

2 MacDonald, A. C.: "Alleged Traces of Primitive Man." Austral. Min. Stand., vol. xxxi., 1904, p. 274.

3 *Ibid.*, pp, 230-231, 273-274.

4 See for example, Pritchard, G. B.: "The Sand Dunes of the Coast." Geelong Naturalist, vol. iv, No. 3, March, 1895, pp. 43, etc.

thin clayey layer, as if the people who made them had had muddy feet. The material that filled the cavities is said to have come away on the under surface of the overlying slab.

This slab is not convincing. The flat, smooth depressions look not unlike those that would be formed by a naked person sitting on the sand; but if so, the proportions between the width of his buttocks and the width of his feet (3 inches) were abnormal. It is therefore held that the impressions were made by two persons sitting side by side; and Mr. McDowell tells me that a slight ridge once marked the division between the buttocks on the larger impression, but it has since crumbled away. If the two depressions are to be regarded as having been made by two naked people sitting on the sand, the slab does not seem to me to look like it. The interval between the impressions is only $\frac{7}{8}$ of an inch, which is too little. It is accordingly explained that the man got up first, and that the woman moved slightly to her left as she rose, and thus caused the narrowness of the ridge. One would have expected that the regularity of the curve of the impression left by the man would have been marred by the same movement.

The supposed buttock impressions may be such, but they may be merely hollows formed by wind eddies. How the supposed footprints were formed I have no definite opinion. They look more like the impressions that would be left by booted, than by naked, feet; and Mr. McDowell tells me that such is the general opinion of those who have examined the specimens. It has indeed been suggested that they were made by some early explorer who landed on this coast. The width of the footprint seems to me too uniform to have been made by a naked foot; the cavity is deepest at the toe end where the foot should have made a much wider impression than at the heel. The greater depth of the front of the footprint seems to me improbable in the case of footprints made by people descending the steep slope of a loose dune. I have had some practice in following the footprints of East African negroes, and these marks do not appeal to me. They seem to me unlike naked footprints, but to resemble a careless man's idea of what human footprints would be like.

If this slab be evidence that aboriginal man lived in Warrnambool at the time that the lower beds of the Warrnambool sand-

stone were being laid down, I think it is also evidence that those people wore a modern type of boot. In that case Professor Spencer's view that the Australian aborigines show no signs of degeneration will have to be seriously reconsidered.

V.—Traditions of the Victorian Eruptions.

Aboriginal traditions, however, are quoted in support of the view that man was contemporary with some of the Victorian volcanic eruptions. It is stated that the aborigines reported that various rocks, now lying on the surface of the ground, were thrown from the adjacent volcanic hills. This tradition is quoted in reference to Mount Buninyong, near Ballarat.[1] Mr. T. S. Hart tells me that an old resident in the Western district, who arrived there in 1847, but who is now dead, told him the same about Mount Elephant. Again, Mount Leura, according to a tradition current in the Camperdown district, was built up of material thrown out of the basins of Lakes Bullenmerri and Gnotuk.

One of the most authoritative of these traditions is recorded by Dawson.[2] "Some names of places indicate the existence of heat in the ground at a former period; but no tradition exists of any of the old craters, so numerous in the Western District, ever having thrown out smoke or ashes, with the exception of 'Bo'ok,' a hill near the town of Mortlake. An intelligent aboriginal distinctly remembers his grandfather speaking of fire coming out of Bo'ok when he was a young man. When some of the volcanic bombs found among the scoriae at the foot of Mount Leura were shown to an intelligent Colac native, he said they were like stones, which their forefathers told them had been thrown out of the hill by the action of fire."

Mr. J. Parker tells me that the aboriginals of the Loddon tribe (the Ja-jow-er-ong, or Jajauwurung according to Mr. Howitt's spelling) had a similar story about Mount Franklin; and from the account it appeared to have been in eruption about

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1 *E.g.*, A. W. Howitt: "On the Origin of the Aborigines of Tasmania and Australia." Austral. Assoc. Adv. Sci., vol. vii., Sydney, 1898, p. 753.

2 Dawson, James: "Australian Aborigines, the Language and Customs of several Tribes of Aborigines in the Western District of Victoria, Australia," 1881, pp. 101-2.

200 years before 1830. The crater is occupied by a gum forest and the size of some of the trees would alone throw some doubt upon that date; and Mr. Parker says that the tradition was so vague and uncertain, that both he and his father (who was the official Protector of Aborigines, in charge of the Aboriginal Station at Mount Franklin), thought it was based on an inference from the shape of the crater, and was no proof that man had seen it in eruption. This legend is, however, the most realistic that has reached me; for the aborigines are said to have blown the bellows of the blacksmith's forge, and declared that was how the mountain went in the time of their forefathers.

These traditions appear, at first sight, to show that the aborigines had some knowledge of the eruptions from the now extinct volcanoes. When this evidence is examined more closely, however, its value appears less. It is all very uncertain. These traditions are vague and indefinite; and they have been recorded only from memory, mostly at second or third hand, long after they were heard. They are now little more than traditions of traditions, and are much less graphic than the aboriginal account of earthquakes.[1] Either the traditions themselves or the accounts of them are contradictory. Thus, Dawson says there was one about Mount Shadwell, and denies that there were any regarding Mount Elephant or Mount Leura; and had there been any such, he no doubt would have known of them.

VI.—The Evidence of Aboriginal Names of Extinct Craters.

If the aborigines had seen any of the mountains in eruption, they would probably have given them names which indicated something to do with fire or smoke. It is difficult now to learn the aboriginal place-names and their meanings. Most of the existing vocabularies of the Victorian aborigines were collected by untrained men, who had inadequate knowledge of the native language, and generally recorded the words from memory, spelling them on no definite phonetic system. Such evidence as we have, however, does not connect the names of any of the Victorian

1 Dawson: *Op. cit.*, p.? 102.

craters with volcanic phenomena. The word Fire, among the aborigines, is given by Brough Smyth as Towera,[1] which Mr. Howitt spells Taura. The word for Fire, most widely distributed in Victoria, occurs as Wee, Wein, Ween, Whean, Weeing[2] and Weenth,[3] and even Wanyap.[4] This word is not used for any of our extinct volcanoes, even when there are said to be aboriginal traditions of their activity. Toong,[5] the word for smoke among some of the western aborigines does not appear in connection with the craters; but Towera does occur in the native name Kutbuntaura, on the Macallister River, above Glenfallock, which, however, is not of volcanic origin. Boort, another term for smoke, is a well-known place-name, but, so far as I know, is not used for any volcanic crater. There are statements, however, connecting the names of some craters with fire; thus, Bonwick[6] says that Koroit, the aboriginal name of Tower Hill, one of the most recent of Victorian volcanoes, means "fire." He gives no authority for this meaning, and Brough Smyth's informants variously give the name as Koroitch, a small fish,[7] Korite, a "large male kangaroo,"[8] or as "the male kangaroo."[9] Koroit is also interpretated as nettles.[10] The native name of Mount Elephant, which also has traditions connecting it with eruptions, is said by Brough Smyth to be Tirrenchillum or Tarrinallum, and to mean a "hill of fire."[11] I was informed locally that the name Terrinallum or Djerrinallum[12] means the "tern," flocks of which lived on the plains around the mountain; and, as I have already remarked, according to Dawson, the natives had no tradition of any eruptions of Mount Elephant. Dawson's definite statement that the aborigines of the Camperdown district connected Mount Shadwell only, with volcanic action, seems to me to outweigh

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1 Smyth, Brough: "The Aborigines of Victoria," vol. i., London, 1878, p. 458.
2 Smyth. *Op. cit.*, vol. ii., pp. 12, 13, 83, 85, 86.
3 Bunce, D.: "Language of the Aborigines of the Colony of Victoria," Geelong, 1859, p. 17.
4 Smyth, Brough: "The Aborigines of Victoria," vol. ii, p. 10.
5 Curr, E. M.: "The Australian Race," vol. iii., 1887, pp. 491-493.
6 Bonwick, James: "Western Victoria," Geelong, 1858, p. 62.
7 Smyth, Brough: "The Aborigines of Victoria," vol. ii., p. 186.
8 Smyth: *Op. cit.*, p. 213.
9 Smyth: *Op. cit.*, p. 210.
10 Gregory, J. W.: "Teaching of Geography," 1902, p. 50.
11 Smyth, Brough: "The Aborigines of Victoria," vol. ii., p. 214.
12 Gregory. *Op. cit.*, p. 49.

the vague secondhand reports connected with Mount Elephant and Mount Leura; for Dawson is probably the best available authority for the aborigines of that district. Dawson did not know the meaning of the name Bo'ok,[1] which is given by Brough Smyth as Poork or Porrhuc, and it is said to mean "a cold in the head,"[2] probably implying that the mountain was as cold and bleak, when it was first named by the aborigines, as it is now. That Mount Shadwell was the last volcano in its district in eruption is geologically improbable; for it looks much older than the craters of Mount Noorat, respecting which there are no traditions.

The meaning of the names of extinct craters always seems to imply that the hills were in much the same condition when they were named by the aborigines, as they are to-day. Thus Mount Leura, or Lehuura, is said by Dawson[3] to mean "nose," referring no doubt to the shape of the denudation curve of the northern face of the mountain. Mount Buninyong is said[4] to mean the "knee hill," from "bunin"—knee, and "youang"—a hill; the latter term is familiar in the name of the You Yangs, and occurs with the Loddon tribe under the form of Yon-arng, a hill.[5] The name Buninyong was apparently given to the hill from its resemblance to the bent knee of a man lying on his back. This fact indicates that Buninyong was in its present, worn down, denuded condition, when the aborigines named it.

Mount Warrenheip, east of Ballarat, is said to mean emu feathers, and was given from the feathery aspect of the tree ferns that flourished on the slopes of the hill. The term again suggests that the volcanic fires had been extinct, and that the mountain was covered with vegetation when the aborigines first knew it.

VII.—The Traditions and Geological Evidence.

Another strong argument against the historic value of these traditions is that they do not agree with the geological evi-

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1 Dawson, James: "Australian Aborigines, the Language and Customs of several tribes of Aborigines in the Western District of Victoria, Australia," 1881, p. 79.

2 Smyth, Brough: "The Aborigines of Victoria," vol. ii., p. 214.

3 Dawson, James: "Australian Aborigines," p. 80.

4 Withers, W. B.: "History of Ballarat," 1870, p. 10.

5 *Smyth, Brough*: "The Aborigines of Victoria," vol. ii., p. 162.

dence, for they do not refer to the craters which were last in eruption. Thus, Mount Leura is probably older than some other mountains in the same district, e.g., than Mount Noorat, of which the crater is perfect. Accordingly one would expect, if there were any reliable aboriginal traditions of volcanic action in the Camperdown district, that they would refer to Mount Noorat, rather than to Mount Shadwell, Mount Elephant, or Mount Leura. Warrenheip is in a much better condition of preservation than Buninyong; its crater walls are far more perfect, and as the two mountains are equally exposed, Warrenheip was probably in eruption much the later. Traditions of volcanic activity in the Ballarat district should refer to Warrenheip rather than to Buninyong.

The origin of these traditions is easily explained without accepting them as historic. Some of the Victorian craters resemble the form of the aboriginal ovens; the vesicular basalts look like cinders, and burnt, carbonized tree-stems occur in the lava flows. The igneous origin of the mountains would be obvious to even less keen observers than the Australian aborigines. Moreover, the people who asked the aborigines as to the former eruptions from the mountains, probably put leading questions, and may thus have themselves originated the traditions. The aborigines had many legends, which no doubt arose from the endeavour to explain natural objects. The traditions that stones lying about Buninyong and Mount Elephant have been thrown from the craters is not an unnatural invention to explain the occurrence of the numerous volcanic bombs on their flanks. The folk-lore of most nations contains legends of stones being thrown to their present positions by giants, or by the elements in fury. Thus, the hills of liver-coloured quartzite, near the end of Lake Eyre, are reported to be the liver of one of the Mura-mura, the legendary giant forerunner of the present aborigines. This Mura-mura was dying and was harassed by dingoes, and in his agony he tore out his liver and threw it away. The idea that these hills had been thrown where they are was, to the aborigines, the easiest method of explaining their existence. If these hills had been composed of volcanic materials, instead of quartzite, the legend might have been quoted as proof that the aborigines witnessed the eruption.

The legend that Mount Leura is the heap of material thrown out of the two adjacent lake basins, would be so incorrect as a matter of fact, that it tells against the idea that the story was based on observation. The form of the two basins suggests that they were formed by subsidence and not by explosion; but it was only natural for the aborigines to regard them as excavated, and to attribute the nearest hill to the material obtained therefrom.

VIII.—Traditions of Geographical Changes.

Suggestions of the antiquity of man in Victoria, based on aboriginal knowledge of geographical changes, are equally uncertain. The former occurrence of sharks in the Mitchell River,[1] or the former full connection of Lake Tyers with the sea, and other similar reports, only indicate comparatively slight changes, and no long lapse of time. The strongest evidence derived from geographical changes is that adduced by Mr. Howitt in his argument that man crossed from Victoria to Tasmania before the formation of Bass Strait[2]; but his general arguments, though weighty, are themselves indirect, and do not seem adequate to counterbalance the overwhelming geological evidence in favour of the separation of Tasmania long before the possible arrival of man.

IX.—The Possible Occupation of Victoria by a Pre-Aboriginal Race.

The weakness of the traditional evidence would not, however, alone be conclusive against the Buninyong implement having been cut and buried by aboriginal man; for the traditions of the late Victorian aborigines is only evidence of the condition of Victoria since their entry. There may have been an earlier race, whose legends and place-names died with them. The possible occupation of Victoria by a pre-aboriginal race, which may have been contemporary with the volcanoes, has one consideration in its favour. The theory of the origin of the Australasian aborigines which appears to be now generally accepted, is that they

1 Howitt, A. W.: "Notes on the Geology of Part of the Mitchell River Division of the Gippsland Mining District." Prog. Rep. Geol. Surv. Vict., No. 2, 1874, p. 70.

2 Howitt, A. W.: Add. Austral. Assoc. Adv. Sci., vol. vii., Sydney, 1898, p. 755.

were originally a negroid race, of which the Tasmanians are the only historic representatives. It is thought that the members of this race crossed Australia as far as Tasmania, wherein some of them were isolated by the formation or enlargement of Bass Straits. Australia was then invaded by a race of black Caucasians, who intermixed with the negroid occupants of the continent, and the Australian aborigines were the offspring of this mixture. The negroid people were thus replaced in Australia, but survived in Tasmania. According to this theory we should expect Victoria to have been occupied by members of the primitive Tasmanian race, which became extinct long before the arrival of the recent aborigines. Hence, men of the Tasmanian race may have lived during the volcanic period, and yet all traditions and place-names founded on the eruptions may have been lost. If the aborigines had overlapped with the Tasmanian people, the few doubtful traditions previously quoted, might be regarded as the distorted fragments of information, which the present aborigines obtained from their predecessors.

We have, therefore, to consider whether the Buninyong implement, for that is the only one worth considering, may have belonged to a pre-aboriginal Tasmanian race. The Tasmanian stone implements were of a ruder type than those of the Australians; they were merely chipped and never ground, and apparently they were not used in handles. From their shape they have been described by Professor E. B. Tylor as quasi-palaeolithic. Mr. Kenyon tells me that, though he has searched carefully in the hope of finding beds in Victoria containing only roughly chipped implements, which cannot be distinguished from those made by the Tasmanians, he has found none.

The only area on the mainland of Australia, where implements occur which resemble the Tasmanian, is in Westralia. Thus, according to Brough Smyth, the typical implement in that area "is ruder in its fashioning, owing principally to the material of which it is composed, than even the rude unrubbed chipped cutting-stones of the Tasmanians."[1] Professor Tylor[2] and Mr.

1 Smyth, Brough: "Aborigines of Victoria," vol. i., London, 1878, p. 340.

2 Taylor, E. B.: "On the Survival of Palaeolithic Conditions in Tasmania and Australia." Brit. Ass. Adv. Sci., 1898, p. 1015.

A. Morton, of Hobart, have re-asserted this similarity in the case of the implements from the Murchison district of Westralia.

The Western Australian implements, though rough, were mounted in wooden handles, a device the Tasmanians apparently did not know; and the Western Australian aborigines who used the roughly chipped stones, had other implements better than those of Tasmania. The roughness of these unchipped Westralian stones does not prove any direct affinity between their makers and the Tasmanians. There is indeed no geological evidence of the passage of the Tasmanian race across Victoria; and certainly the Buninyong bone gives none, for it is of a more advanced, rather than of a simpler type of workmanship, and the Tasmanians apparently did not use bone implements.

Mathew[1] has made the interesting suggestion that the stories of Looern, the wild man of the Hoddle Range, north of Wilson's Promontory, and of Wiwonderrer, the man-like animal, with a body as hard as stone, who lived on the Bass Range, east of Western Port, may be based on some of the last Tasmanian survivors on the mainland. If so, then layers with implements, all of the roughly chipped Tasmanian type, should be found in that district. But so far I know of none; on the contrary, the implements I have seen from Wilson's Promontory, and near Foster, are above the average workmanship of Victorian stone implements. Geological evidence so far gives no positive evidence as to the route by which the Tasmanians reached their island home. There is one area in Victoria, the Gippsland Lakes estuary, which has formed by subsidence at a comparatively recent date. That area might have been occupied by a pre-aboriginal race, and the evidence all buried. But even then we should have expected traces of these people on the surrounding lands.

X.—The Length of the Human Occupation of Victoria.

We have seen that the evidence of the aboriginal traditions gives no certain support to the view that man witnessed any of the volcanic eruptions in Victoria. Some of the traditions, moreover, tell against this view, as they affirm that man entered Victoria at a comparatively recent date.

1 Mathew, J.: Eaglehawk and Crow, 1899, p. 19.

Mr. J. Parker tells me that the aborigines of the station on Mount Franklin had a legend that their ancestors entered Australia in a canoe, and that they travelled into Victoria from the west. Mr. Parker says that his father concluded that, according to the legends, the aborigines only arrived here 300 years before the British occupation. This evidence alone would not be worth much; but so far as I know, all the direct available evidence agrees with it. The oldest bed in which stone implements have been found need not be more than a few centuries old. The evidence is overwhelming that the implements occur only in the superficial layers or in beds such as river silts and sand dunes, which may accumulate with extreme rapidity.

Mr. Robert Etheridge has discussed the evidence of the age of man in New South Wales, and has concluded that the antiquity of man in that State also is unproven.[1]

The negative evidence is equally striking in reference to Queensland. Mr. Etheridge asks "Has man a geological history in Queensland?" and says "that answer to this question may be given in one word—No! That is to say, so far as I am aware, no evidence of the presence of man, or of his works, has yet been discovered in any raised beach, cave or stratified deposit associated with the remains of extinct animals."[2]

The late Professor Tate, of South Australia, believed in the Pliocene age of Australian man; but his belief rested only on the doubtful assumption that man necessarily entered at the same date as the dingo.

The general evidence seems to me to point to the conclusion that the aborigines have resided in Victoria for but a short period. It is true that the division of the Victorian aborigines into so many distinct tribes at first suggests their long residence in the country, but this would only be so if the tribes had developed here. The aborigines, however, were divided into

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1 Etheridge, R., jun.: "Has Man a Geological History in Australia?" Proc. Linn. Soc. N.S.W., 1890, vol. v. (2nd ser.), Sydney, 1891, p. 259-266. Also "Contributions to a Catalogue of Works, Reports and Papers on the Anthropology, Ethnology and Geological History of the Australian and Tasmanian Aborigines." Dep. Mines. Mem. Geol. Surv. N.S.W., Palaeontology, No. 8, Pt. I., Sydney, 1890, p. 3. Full references to the literature of Aboriginal Stone Implements and Ovens will be found in this catalogue, of which Pt. II. was issued in 1891, and Pt. III. in 1895.

2 Jack and Etheridge: "Geology of Queensland," vol. i., 1892, p. 622.

distinct tribes before their arrival in Victoria. They probably came from the north, but some entered Victoria by western, and others by eastern routes, and these two trains of immigrants met in Central Australia. There is no doubt, the authority of E. M. Curr for the view that some of the tribal divisions in Gippsland developed in Victoria; for he says that the Gippsland tribes were the last offshoot of the Australian race, and they had existed long enough to have developed considerable differences in language. But he gives no proof that the common ancestor of the Gippsland tribes lived in Gippsland. He supports his position by reference to the mussel shells on the banks of the Murray, buried a foot or two, or perhaps more, by silt.[1] But a single flood may deposit a couple of feet of silt.

The tribal distinctions only prove the antiquity of the tribes, and not their long residence in Victoria. That they have not been here for a great length of time is suggested by their comparatively small number, moreover, is consistent with their not having been here for a great length of time. No accurate census was ever made of them, but Brough Smyth, discussing the various estimates that had been previously made, concludes that the total number of aborigines in Victoria, at the first discovery of the country, was only about 3000;[2] Mitchell's estimate was lower, and Thomas's, the highest official estimate considered by Smyth, was 6000. E. S. Parker,[3] the head of the aboriginal station at Mount Franklin, calculated the number in Victoria at 7500. These estimates may be too low, but I have heard of assemblies, in the Loddon district, attended by over 3000 aborigines, but the memory of my informant probably led him to exaggerate the number. When we remember that Thomas's census[4] of the aborigines of Western Port (the Bunurong) and the Yarra tribe (the Warurong) in 1839 amounted only to 207 individuals; that Gray's census for the Portland Bay district, extending from the Glenelg to Colac, was only 599; that C. J. Tyers[5] estimated the

1 Curr, E. M.: "The Australian Race," vol. i., 1886, pp. 206-7.
2 Smyth, Brough: "The Aborigines of Victoria," vol. i., London, 1878, p. 35.
3 Parker, E. S.: "The Aborigines of Australia." A Lecture, Melbourne, 1854, p. 14.
4 Archer, W. H.: "Statistical Register of Victoria," 1854, p. 230.
5 "Letters from Victorian Pioneers," edited by T. F. Bride, Melbourne, 1899, p. 79.

aboriginal population of Gippsland in 1843 as 1800; and that H. Jamieson,[1] of Mildura, considered that there were only 1500 in the country on both banks of the Murray from Swan Hill to the South Australian border, and for 500 miles up the course of the Darling; then Brough Smyth's estimate is not incredible, though it may be somewhat too low.

The limited distribution of the aborigines in Victoria is more significant. They only inhabited certain parts of Victoria; they lived in the country that was most easily occupied; and other districts, which would have yielded a fair supply of food, but were not easily found, were practically unentered. Mr. Kenyon tells me that there is no trace of their occupation in the forests of the Otway ranges; and in the higher parts of Gippsland they appear to have been only casual visitors. In the Mount Useful country occasional stone tomahawks have been found, apparently along the routes by which the aborigines traversed the country; for localities, which would have made excellent camps, appear to have been quite unvisited. According to Mr. Howitt, for example, Lake Karng was probably unknown to the aborigines until "about the time when Angus MacMillan discovered Gippsland" (*i.e.*, 1839).[2] Not only were various parts of the country unentered, but no special hill or forest tribes appear to have been developed, as there probably would have been had the country been long in the occupation of man. Mr. Howitt tells us that in the dense jungle that covers the country east of the Snowy River there "was a small tribe of 'no-man's-men,' called the Bidueli, who were neither Kurnai (of Eastern Victoria) or Murring (of New South Wales). They were probably broken men and fugitives from the surrounding tribes."[3] Had Victoria been long occupied, there would probably have been such Adullamite clans in various parts of Victoria.

XI.—Conclusion.

A general survey of the evidence known to me, therefore, shows that, however ancient the Australian aborigines may be,

1 "Letters from Victorian Pioneers," edited by T. F. Bride, Melbourne, 1899, p. 272.
2 Howitt, A. W.: "Notes on Lake Karng." Quart. Rep. Min. Dep. Vic., Sept. 1891, p. 26
3 Howitt, A. W., and Fison, L.: "The Aborigines of Victoria." Handbook of Melbourne, for the use of Members of the Austral. Assoc. Adv. Sci., Melbourne, 1900, p. 46.

there is no evidence of the long occupation of Victoria by man. This conclusion is unexpected; it is in opposition to preconceived anthropological opinion; it is opposed, I fully admit, to what are apparently the obvious probabilities of the case. Nevertheless, the geological evidence suggests that man has not been resident in Victoria for any prolonged period. This conclusion is not likely to be accepted by anthropologists without the utmost reluctance; but if it be wrong, abundant evidence to disprove it ought to be readily forthcoming. The main object of this paper is to call forth the evidence for the antiquity of man in Victoria, if such evidence there be.

ART. V.—*Revision of the Australian Aphodiides, and Descriptions of Three New Species allied to them.*

BY REV. T. BLACKBURN, B.A.

(Communicated by the Hon. Secretary).

[Read 9th June, 1904.]

SCATONOMIDES.

Thyregis, gen. nov.

Corpus oblongum, convexum; clypeus antice emarginatus; palporum maxillarium articulo apicali elongato, manifeste acuminato, mentum antice emarginatum; palporum labialium articulis 1°, 2°que sat aequalibus leviter dilatatis, 3° angustiori paullo breviori; antennae 9-articulatae; prothorax subtus ad caput recipiendum vix impressus; scutellum valde minutum sed haud plane obtectum; elytrorum epipleurae angustae; coxae anticae fere ut Coptodactylae sed inter femora nonnihil latiores; coxae intermediae sat parallelae; metasternum elongato-quadratum, episternis modicis (fere ut Coptodactylae); pygidium (exempli typici) verticale; tibiae anticae extus tridentatae, subtus carina marginatae (ut Coptodactylae); tarsi antici modici; tibiae posticae apicem versus fortiter dilatatae, extus bidentatae, ad apicem sat longe setosae et calcari modico armatae; tarsi postici modici, articulis basali sat brevi fortiter triangulari (quam ad apicem latus haud longiori) 2° quam basalis vix breviori sed multo angustiori 3° 4°que gradatim paullo brevioribus et angustioribus 5° quam praecedentes 2 conjuncti sublongiori; unguiculi parvi; abdomen medium brevissimum, suturis bene definitis.

I cannot find any described genus of the Coprides having the above characters in combination. According to Lacordaire's classification, this species must stand in that author's group Scatonomides, on account of its having the third joint of its labial palpi well developed and its front coxae not prominent; and the following characters place it (among the genera of that group) beside Choeridium, viz.:—Elytral epipleurae narrow, ventral sutures well defined, sides of elytra not emarginate, front

coxae not exceptionally large, hind tibiae toothed externally. It differs from the characters that Lacordaire assigns to Choeridium (and Scatimus, which he places beside Choeridium) by the very decidedly dilated first and second joints of its labial palpi, and also from Choeridium (I have not a specimen of Scatimus for comparison) by the apex of its front tibiae not truncate, by the strong teeth of the external margin of its posterior tibiae (which are much like those of Coptodactyla), and by the very much more strongly dilated basal joint of its posterior tarsi. The non-truncate apex of the front tibiae would seem to forbid this insect being placed in the sub-group of the Scatonomides which Harold names the Choeridiides, but it certainly has many structural characters of that sub-group, and I know not where else to place it. The presence of a minute scutellum appears to be a remarkable character, but in this it is closely approached by Coptodactyla, in which the scutellum is perfectly visible (although it does not quite rise to the dorsal surface of the elytra) when the prothorax is not quite in contact with the base of the elytra. Two genera of Scatonomides have previously been reported as Australian—Pedaria, to which Harold refers Aphodius geminatus, Macl., and Coptodactyla, which (as Harold has pointed out) is a Choeridiid, notwithstanding Lacordaire's having treated it as a subgenus of Copris. I may say, in passing, that I am not altogether satisfied with Harold's reference of Aphodius geminatus to Pedaria, inasmuch as its ventral sutures appear to me to be perfectly well defined, but as I have not an authentic specimen of Pedaria (other than A. geminata) for comparison, I am not in a position to deal with the matter confidently. The present genus differs from Coptodactyla and Pedaria by *inter alia multa* the non-truncate apex of its front tibiae.

T. KERSHAWI, sp. nov.

Oblongus; sat latus; fere glaber; sat nitidus; niger antennis et pedum setis ferrugineis, pedibus picescentibus; capite transversim rugulato; clypeo antice bifido; fronte media leviter obtuse trituberculata; prothorace quam longiori vix plus quam sesquilatiori, transversim subquadrato prope apicem sat angustato, supra aequali (fovea sublaterali utrinque posita magna

excepta), fortiter crebre nec rugulose punctulato, angulis anticis bene determinatis leviter obtusis posticis rotundato-obtusis, basi marginata; elytris profunde 10-striatis (striis 9^0 10^0que in parte posteriori conjunctis), striis duplici serie (fere ut Coptodactylae glabricollis, Hope, sed puncturis minoribus et crebrioribus) punctulatis, interstitiis convexis minus perspicue punctulatis; pygidio fortiter crebrius punctulato.

Long. 4 l. Lat. $2\frac{1}{4}$ l.

To a casual glance extremely like a small Coptodactyla, but, as indicated in the generic diagnosis, with very different structural characters. I am uncertain of the sex of the type, but regard it as probably a male on account of the transverse row of three tubercles on its forehead; these, however, are quite small, and are feeble conical projections of the upper outline of an ill-defined, obtuse, transverse carina.

Victoria; sent to me by Mr. J. A. Kershaw.

ONTHOPHAGIDES.

Onthophagus.

O. CARTERI, sp. nov.

Sat brevis; minus nitidus; supra breviter fulvo-setosus; subtus sparsim setis fulvis sat brevibus vestitus; niger palpis antennisque ferrugineis, harum clava testacea; clypeo transversim ruguloso antice fortiter emarginato; carina frontali nulla; oculis minus angustis, nitidis, sublaevibus; prothorace quam longiori ut 17 ad 11 latiori, supra confertim aspere (fere ut O. Adelaidae, Hope) punctulato, fovea sublaterali sat fortiter impressa, lateribus ante medium perspicue (pone medium vix manifeste) sinuatis, angulis anticis peracutis (subspiniformibus), basi subtilius lineato-marginata; elytris minus perspicue striatis, interstitiis obsolete sub-granulatis antice planis postice leviter convexis; pygidio sat grosse ocellato-punctulato; metasterno toto sat grosse punctulato; unguiculis sat parvis.

Maris sutura clypeali vix manifesta; pronoto antice perspicue retuso.

Feminae sutura clypeali perspicue carinata; pronoto antice vix retuso.

Long. $4\frac{1}{5}$ l. Lat. $2\frac{1}{2}$ l.

Not unlike O. Adelaidae, Hope, but with the sexual characters of quite different description, the elytra much less distinctly striate with interstices flatter, and closely set with minute setiferous granules, the eyes considerably wider, and on their surface only very feebly facetted, etc. It must stand beside O. Macleayi, Blackb., in my tabulation (T.R.S. S.A., 1903, pp. 267, etc.), from which, however, it is extremely distinct by many characters (*e.g.*, the confluent asperate puncturation of its pronotum).

N. S. Wales; Sydney (Mr. Carter).

O. JUNGI, sp. nov.

Sat brevis; modice nitidus; supra glaber; subtus sparsius fulvo-pubescens; niger; capite crebrius fortiter punctulato; oculis angustis perspicue granulatis; prothorace quam longiori ut 5 ad 3 latiori, postice longitudinaliter obsolete sulcato, crebre subgrosse punctulato, fovea sublaterali sat profunda, lateribusante medium haud (pone medium leviter) sinuatis, angulis anticis obtusis posticis rotundatis, basi sat fortiter lineato-marginata; elytris sat fortiter punctulato-striatis, interstitiis convexis sparsim minus subtiliter punctulatis; pygidio metasternique disco sparsius sat grosse punctulatis; unguiculis sat parvis.

Maris clypeo antice fortiter emarginato; capite inter oculos tricornuto; cornubus lateralibus elongatis arcuatis (his intus prope basin dente sat elongato instructis), intermedio brevi conico fere ad cornuum lateralium dentem aequali; carina clypeali fere nulla; pronoto antice sat alte retuso, parte retusa obsolete punctulata; elytrorum interstitiis leviter punctulatis.

Feminae clypeo antice obsolete emarginato; carina clypeali bene determinata in medio dentata; capite inter oculos sat alte carinato; pronoto antice leviter vel vix retuso; elytrorum interstitiis sat profunde punctulatis.

Long. $3\frac{3}{5}$ l. Lat. $2\frac{1}{5}$ l.

This species stands in my tabulation (T.R.S. S.A., 1903, pp. 267, etc.) besides henleyensis, Blackb., to which it is closely allied, but the sexual characters are extremely different. I know no other Australian Onthophagus in which the frontal elevation in the male at all resembles that of the present species, and the

female differs from that of O. henleyensis in the clypeal carina being elevated in the middle into quite a strong tooth.

S. Australia; Yorke's Peninsula (Mr. Jung).

APHODIIDES.

This group (Lacordaire's second tribe) of the sub-family Coprides is readily distinguished from the true Coprides (Lacordaire's first tribe) *inter alia* by the presence of two spines at the apex of the hind tibae—the true Coprides having only one spine. It is largely represented in Australia in respect of species, and fairly numerously in respect of genera. Masters' Catalogue enumerates 14 species attributed to five genera; and since the publication of that catalogue 20 species have been added, one of them appertaining to a genus not previously recorded as Australian (Rhyssemus). One genus and species, however [Pedaria (Aphodius) geminatus, Macl.], has been shown to be wrongly attributed to the group, and one generic name (Proctophanes, nom. praeocc.) has been replaced by a new name (Proctammodes). Moreover, there is a want of evidence of the occurrence in Australia of one of the genera (Ammoecius) enumerated by Masters. Eight species have been attributed (all by Macleay) to Ammoecius, some of which are known to me somewhat certainly, and I do not find a genuine member of the genus among them, or among the other Australian Aphodiides that I have had the opportunity of examining. I furnish below some notes on the species that Macleay described, and add descriptions of a number of new species, among which will be found representatives of Psammodius and Saprosites—genera that have not hitherto been recognised as Australian—and also a species that I place with some hesitation in Euparia (another genus not previously recorded as Australian).

The following tabular statement shows the characters that I have relied upon in apportioning the species before me to their genera. As there are, among the new species described below, a few that do not seem quite typical representatives of the genera in which I have placed them, and which may possibly be attributable to closely allied genera unknown to me that may have been formed for Aphodiides of regions outside Australia (the Aphodiid genera being for the most part widely distributed), it seems well to note the fact that I have referred the species to

genera strictly on the characters cited below. This statement will prevent any difficulty arising in identifying my new species, even if it should prove that any new genera have been founded elsewhere based on the peculiarities mentioned below in some of the species described. The principal instance of doubtful apportionment occurs in Saprosites, some of the species I attribute to this genus having the intermediate coxae considerably more widely separated *inter se* than they are in the American species before me. I cannot, however, ascertain that any genus has been formed at the expense of Saprosites on this character, nor does it appear to me a sufficient character for the establishment of a new genus.

A.—Mesosternum declivous between intermediate coxae—not continuing plane of metasternum.
  B.—Dorsal surface of elytra not having a basal edging.
    C.—Intermediate coxae approximate - - - Aphodius.
    CC.—Intermediate coxae widely separated from each other - - - - Proctammodes.
  BB.—Dorsal surface of elytra having a basal edging.
    C.—Hind femora oblong or subparallel (their tibiae narrow, not or scarcely dilated externally).
      D.—Pronotum not transversely sulcate.
        E.—Sides of pronotum normal - - - Ataenius.
        EE.—Sides of pronotum explanate - - Euparia.
      DD.—Pronotum transversely sulcate - Rhyssemus.
    CC.—Hind femora short and wide, their front outline strongly arched - - Psammodius.
AA.—Mesosternum horizontal, continuing the plane of the metasternum.
  B.—Labrum and mandibles normal - - - Saprosites.
  BB.—Labrum and mandibles protruded - - Saprus.

Aphodius.

The Australian species of this genus differ from all the other Australian Aphodiides observed by me (except the two species of Proctammodes) in that the dorsal surface of the elytra passes

to the front declivity quite evenly, without a trace of a defined margin. An examination of my comparatively small collection of Aphodiides from other parts of the world leads me to the opinion that this is an important character for dividing the Aphodiid genera into groups, although I do not find it referred to by Lacordaire or Erichson (who both furnished tabulations of the Aphodiid genera known to them), nor is it mentioned in any of the works in my possession of de Harold.

This cosmopolitan genus (containing some cosmopolitan species) is not, so far as I can judge, very numerously represented in Australia. Master's Catalogue enumerates 7 species (2 of them certainly introduced), 6 have been added subsequently, and I now have 4 more to add, making a total of 17. As the Aphodii are easily collected, and neither very small nor very obscure insects, it is unlikely that an exceptionally large proportion of them have hitherto escaped notice. When it is remembered, then, that Erichson enumerated (A.D. 1848) 79 species as known in Germany alone, it certainly appears likely that Australia is not rich in the genus. As far as I know all the 17 names represent valid species.

Of the described species 4 are unknown (or only doubtfully known) to me, viz., albertisi, Har.; australasiae, Bohem.; candezei, Har.; and erosus, Er. I am not able to place them in the following table on account of the structure of their eyes not having been sufficiently indicated by their authors. I therefore supply the following notes on them.

A. ALBERTISI, Har.

I have specimens from tropical Queensland (Harold's locality) of an Aphodius which must, I think, be very near Albertisi, but as it departs from the description in several details of punctuation I cannot confidently identify it. The elytral interstices (*e.g.*) of Albertisi are described as "lisses," while those of the specimens before me are, under a good lens, distinctly (though very finely) punctulate. In the following tabulation the specimens before me fall beside A. granarius and frenchi, differing from both by their testaceo-ferruginous color, from the former by the very distinct puncturation of their pronotum and from the latter by the much greater sparseness of the same.

A. AUSTRALASIAE, Bohem.

I have not seen any Aphodius that seems likely to be this species. It is probably near A. frenchi, Blackb., but differs from the latter *inter alia* by the presence on the pronotum of a longitudinal median line devoid of puncturation.

A. CANDEZEI, Har.

This species is said to be from Adelaide. I have not met with it myself nor seen it in any of the numerous South Australian collections that I have examined. It seems to be very distinct from the other described Australian Aphodii. It is of moderate size (long. 3½ l.), with testaceous elytra, on which there are some defined fuscous markings.

A. EROSUS, Er.

There is a single example (from Tasmania—Erickson's locality) in Mr. Griffith's collection which is probably this species; but as it is, in that case, a rather extreme colour variety, I do not feel justified in treating it as definitely identified without having seen a typical specimen. Some further remarks on it will be found (below) under A. suberosus, Blackb. In the following tabulation its place is presumably beside A. insignior, Blackb., from which it differs, *inter alia*, by its sexual characters.

TABULAR STATEMENT OF CHARACTERS OF AUSTRALIAN APHODII.

(Exclusive of the four species discussed above).

A.—Surface of eyes nitid, and facetted only very feebly (all large species).
B.—Base of pronotum margined - - yorkensis, Blackb.
BB.—Base of pronotum not margined.
C.—Hind angles of prothorax entirely rounded off - - - - andersoni, Blackb.
CC.—Hind angles of pronotum very obtuse, but distinctly indicated.
D.—The elytra entirely clothed with pubescence - - - - tasmaniae, Hope.
DD.—The elytra pubescent only near the apex - - - - howitti, Hope.

AA.—Surface of eyes more opaque, very conspicuously facetted.
B.—Elytral intertices, *inter se*, equal or nearly so.
C.—The pronotum unicolorous.
D.—The pronotum scarcely punctulate granarius, Linn.
DD.—The pronotum closely and somewhat strongly punctulate - - frenchi, Black.
CC.—The pronotum bicolorous - - - lividus, Oliv.
BB.—Some of the elytral interstices tuberculate or more elevated than the rest.
C.—The pronotum closely and evenly punclate.
D.—The alternate elytral interstices nontuberculate - - - - victoriae, Black.
DD.—The alternate elytral interstices tuberculate - - - - suberosus, Blackb.
CC.—Pronotum punctured neither closely nor evenly.
D.—The alternate elytral interstices strongly tuberculate - - insignior, Blackb.
DD.—The alternate elytral interstices not tuberculate.
E.—Pronotum nitid.
F.—Pronotum unicolorous - baldiensis, Blackb.
FF.—Pronotum margined with testaceous- - -callabonensis, Blackb.
EE.—Pronotum opaque - - lindensis, Blackb.

A. HOWITTI, Hope.

This species was described very briefly in 1846, and attributed to Victoria, and the next year its author described a species from Tasmania (under the name tasmaniae) in almost exactly the same words. In 1859 de Harold (Berl. Zeit.) reported the two species identical, but in 1861 (*loc. cit.*) stated that he had examined specimens (emanating from Hope himself) in Chevrolat's collection and had found that so far from being identical they had absolutely nothing in common ("durchaus nichts gemein"). In Tr.R.S. S.A. (1892, p. 209), I quoted de Harold's earlier

opinion, and drew attention to the fact that that author did not refer to the sexual characters which are strongly marked. At that time I had not seen de Harold's later note, and I have now to add the remark that I have no doubt of de Harold's statement of the two species having nothing in common being founded upon an examination of two specimens of different sex. I have taken, in Tasmania and Victoria plentifully, Aphodii which I cannot doubt are identical with those on which Hope founded the descriptions referred to above, and have not found in those localities (or seen in numerous collections made there) any others (than those) which come at all near agreement with Hope's descriptions. The Aphodii just mentioned, in my opinion, represent two extremely closely allied species, in both of which the sexual differences (indicated in my paper referred to above) are very well marked, and might not unreasonably be regarded, by an observer who had seen only one of each sex, as specific. As species I find that both vary in colouring too much for any reliance to be placed upon colour. In tasmaniae the prothorax is a little wider than in howitti of the same sex, and its hind angles are a little better defined; the head is, in both sexes, more depressed in its hinder part; and the elytra are clothed on their entire surface (in howitti only near the apex) with fine, very short, inconspicuous pubescence. De Harold seems to have had before him as tasmaniae a female, and as howitti a male. I am by no means confident, however, that they were not two specimens of howitti.

A. ANDERSONI, sp. nov.

Fem. (?) Sat parallelus; sat nitidus; supra (marginibus summis exceptis) glaber; ferrugineus; clypeo sat crebre sat fortiter punctulato, antice rotundato, margine minus fortiter recurvo; fronte minus crebre minus fortiter punctulato; oculis magnis supra nitidis, fere laevibus; prothorace quam longiori ut 8 ad 5 latiori, supra minus fortiter inaequaliter minus crebre minus fortiter (disco postice laevi) punctulato, antice fortiter angustato, latitudine majori pone medium sita, lateribus fortiter rotundatis, angulis anticis obtusis vix prominulis posticis rotundatis, basi haud marginata; scutello modico (fere ut A. tasmaniae, Hope); elytris fortiter striatis, striis nonnihil crenulatis, interstitiis late

subconvexis (2^0 sat crebre nec fortiter ruguloso-punctulato, ceteris magis sparsim plus minusve seriatim, punctulatis), tibiis posticis transversim bicarinatis, setis inter se diversis vestitis.

Long. $4\frac{3}{5}$ l. Lat. 2 l.

An elongate narrow species allied to A. tasmaniae, Hope (differing by, *inter alia*, its nonpubescent dorsal surface), A. howitti, Hope (differing by, *inter alia*, its prothorax much more narrowed in front, with much more strongly rounded sides, having its greatest width notably behind the middle, and with hind corners quite rounded, no trace of an angle), and A. yorkensis, Blackb. (differing by, *inter alia*, the non-margined base of its pronotum. The unique type of this species was given to me many years ago by Mr. J. Anderson, of Port Lincoln. I have little doubt of its being a female, on account of its prothorax notably narrower than its elytra. Its eyes are scarcely visibly facetted.

South Australia (western part of Eyre's Peninsula).

A. SUBEROSUS, sp. nov.

Fem. Oblongus; minus convexus; minus nitidus; supra breviter setosus; luteus, piceo-variegatus, antennis piceis; capite sat crebre sat aequaliter sat fortiter subrugulose punctulato, antice (vix sinuatim) subtruncato; oculis valde perspicue granulatis, prothorace quam longiori sesquilatiori, supra crebre fortiter (subgrosse) sat aequaliter punctulato, longitudinaliter canaliculato, antice parum angustato, lateribus pone medium late profunde excisis, angulis anticis obtusis posticis fere rectis, basi haud marginata; scutello modico punctulato; elytris crenulato-striatis, interstitiis leviter subconvexis coriaceis acervatim punctis setiferis impressis (alternis tuberculis parum elevatis sat magnis ornatis); tibiis posticis transversim bicarinatis, setis inter se diversis vestitis; tibiis anticis extus 3-dentatis.

Long. $3\frac{1}{2}$ l. Lat. $1\frac{2}{5}$ l.

Doubtless allied to A. erosus, Er., but evidently quite distinct, since the colour of that species is described as very different (*e.g.*, the scutellum black), and the puncturation widely distinct (*e.g.*, the pronotum "vage minus subtiliter punctulatum," whereas in this species it is closely, evenly and coarsely punctured), etc., etc.

The dorsal surface of this insect is of a livid brown colour, vaguely and irregularly clouded with piceous on the head and disc of the pronotum, and much mottled with small piceous patches on the elytra. The under surface is brown, more or less clouded with vague infuscation. The male probably has the sides of the pronotum much less strongly excised behind the middle and the front tibiae bidentate externally, as in A. victoriae, Blackb., and (according to description) in erosus, Er.

Victoria (Dividing Range).

A. INSIGNIOR, sp. nov.

Oblongus; minus convexus; minus nitidus supra breviter (in capite pronotoque sat longe); setosus; niger vel nigro-piceus prothoracis lateribus elytris pedibusque luteis; capite sparsissime punctulato, antice late sinuatim truncato; oculis perspicue granulatis; prothorace quam longiori ut 4 ad 3 latiori (feminae paullo magis tranverso), supra sparsissime punctulato, longitudinaliter canaliculato, antice parum angustato, lateribus aequaliter modice arcuatis, angulis omnibus obtusis, basi haud marginata; scutello modico vix punctulato; elytris punctulato-striatis, interstitiis sat planis (3^0, 5^0, 7^0, 9^0que tuberculis piceis sat fortibus seriatim instructis); tibiis posticis transversim bicarinatis, setis inter se diversis vestitis; tibiis anticis extus maris bidentatis (feminae tridentatis).

Long. $2\frac{2}{5}$ l. Lat. 1 l.

Resembles A. erosus, Er., and suberosus, Blackb., in having tuberculate elytra, but differs from both *inter alia* by the hind part of the lateral margin of the prothorax not being excised in the female; also differs from erosus by its scutellum not being black, and from suberosus by the entirely dissimilar puncturation of the pronotum. The tubercles of the elytra on interstices 3, 5 and 7 are considerably better defined than those of A. suberosus, and are on each six or eight in number; those on the 9th interstice are less conspicuous and less numerous.

W. Australia (Swan River). Sent by Mr. Lea.

A. BALDIENSIS, sp. nov.

Mas. Oblongus; minus convexus; minus nitidus; supra breviter (in capite pronotoque longe) setosus; niger, elytris (his piceo-

marmoratis) tarsisque lividis; capite inaequaliter sat grosse punctulato, antice late vix sinuatim truncato; oculis perspicue granulatis; prothorace quam longiori ut 11 ad 8 latiori, supra acervatim sat grosse (fere ut caput) punctulato, longitudinaliter (nisi basin versus obsolete) canaliculato, antice modice angustato, lateribus modice sat aequaliter rotundatis, angulis anticis leviter acutis posticis obtusis, basi haud marginata; scutello punctulato; elytris striatis, striis vix perspicue crenulatis, interstitiis leviter convexis sparsim punctulatis; tibiis posticis transversim bicarinatis, setis inter se diversis vestitis; tibiis anticis extus bidentatis. Long. 3 l. Lat. $1\frac{1}{5}$ l.

Entirely black or piceous-black except the elytra and tarsi. Evidently of the same group as A. erosus, Er.; lindensis, Blackb.; victoriae, Blackb.; suberosus, Blackb.; and insignior, Blackb. I do not think it can be the male of suberosus (of which I know only the female), as its differences from that species are not at all of the kind that obtains intersexually in the species (of the group) of which both sexes are known. The entirely different colouring, the puncturation of the pronotum and the non-tuberculate sculpture of the elytra are most unlikely to be sexual characters. The differences from A. lindensis (also known only by the female) are even greater still.

Victoria; on the higher mountains (*e.g.*, Baldy) of the Alpine Range.

Ataenius.

The Australian species of this genus are probably numerous; notwithstanding their being as a rule much smaller and more obscure insects than the Aphodii, considerably more of them than all the described Australian Aphodii have come before my notice. In Masters' Catalogue, only one species (australis, Har.) stands as Ataenius. Since the date of that catalogue, however, I have myself described seven new species as appertaining to the genus, but two of them (as will be noted below), viz.:—A mendax and zietzi are not correctly placed there, but must be transferred to Saprosites and Psammodius respectively, allied genera which have not been previously recorded as Australian. Sir W. Macleay described eight species as members of the genus Ammoecius, some of which certainly are Ataenii, while one of

them is probably a Psammodius and the rest probably belong to either Ataenius or Saprosites. At present, then, there are, I think, nine described Australian species which may be confidently referred to Ataenius, and three which may be doubtfully placed there. In the following pages I purpose describing 12 new species, and supplying some notes on the three of Macleay's Ammoecii which can be confidently transferred to Ataenius, but before passing to those descriptions and notes, it will be well to make some remarks on the undeterminable species of Macleay's Ammoecii and to furnish a table showing the distinctive characters of the known Australian Ataenii.

A. CRENATIPENNIS, Macl.

In describing the insects he refers to Ammoecius, Macleay does not mention characters that give any definite clue to their generic position, such as the structure of the hind tibiae or of the mesosternum. One can therefore do little more than guess, from the nature of such superficial characters as are mentioned, in what genera they ought to be placed; unless one can see the type or a specimen compared with the type by a thoroughly reliable authority, or at least a specimen agreeing with the scanty diagnosis and known to be from the original locality. As I have none of those advantages in respect of A. crenatipennis I can only say that the description reads like that of an Ataenius which I cannot identify with any species before me.

A. OCCIDENTALIS, Macl.

This is probably an Atoenius or a Saprosites. I incline to deem it the latter.

A. ELONGATULUS, Macl.

Its author makes this species three times as long as wide, and says that it is of "subcylindrical" form, that its surface is opaque and its pronotum very thinly and finely punctulate. I have not, to my knowledge, seen any species resembling it and cannot form any definite opinion as to its genus.

TABLE OF CHARACTERS OF THE AUSTRALIAN ATAENII.

A.—Elytral sculpture consists of well raised
carinae separating granulate intervals.

B.—Each interval between carinae (which are equal *inter se*) bears a single row of granules - - - - - moniliatus, Blackb.

BB.—The elytral intervals and carinae not as B.

C.—Hind angles of prothorax quite rounded off - - - - - - - koebelei, Blackb.

CC.—Hind angles of prothorax well marked.

D.—The alternate carinae (except near apex) obsolete on inner half of the elytra - - - - imparilis, Blackb.

DD.—The elytral carinae equal (or nearly so) *inter se* - - palmerstoni, Blackb.

AA.—Elytral sculpture not as A.

B.—Elytra setulose and granulate - - speculator, Blackb.

BB.—Elytra not both setulose and granulate.

C.—Pronotum not so closely and evenly punctulate as to be without interspaces larger than the adjacent punctures.

D.—Disc of head longitudinally strigose.

E.—Pronotum longitudinally impressed at least near base.

F.—Lateral parts of pronotum opaque and closely rugulose; disc of metasternum strongly and evenly punctulate.

G.—Disc of pronotum decidedly closely punctulate - - australis, Har.

GG.—Disc of pronotum (except near base) quite sparsely punctulate - - sparsicollis, Blackb.

FF.—Lateral parts of pronotum nitid and with deep, coarse punctures; disc of metasternum punctulate only in front semicornutus, Macl.

EE.—Pronotum not longitudinally impressed - - - - - deserti, Blackb.

DD.—Disc of head not longitudinally strigose.

E.—Punctures on disc of pronotum much less close than in australis, Har., not becoming fine and closer in front; head smooth.

F.—Sides of pronotum very nitid and deeply punctured, with a large unpunctured space.

G.—Interstices of elytral striae unusually wide and but little convex - - tweedensis, Blackb.

GG.—Interstices of elytral striae much narrower and much more convex - - - nudus, Blackb.

FF.—Sides of pronotum much less nitid, less deeply and much more evenly punctulate.

G.—Form unusually convex and oval - - - - - gibbus, Blackb.

GG.—Form much more depressed and parallel - - macilentus, Blackb.

EE.—Punctures on disc of pronotum closer (after the manner of australis, Har.), becoming more conspicuously close in front; head usually granulate.

F.—Head entirely and very coarsely granulate (inner side of elytral interstices strongly crenulate) - - - - goyderensis, Blackb.

FF.—Head much less coarsely and not entirely granulate, or non-granulate.

G.—Inner side of elytral interstices deeply crenulate.

H.—Form short, subovate, strongly convex; punctures of pronotum not becoming much finer in front - - - - spissus, Blackb.

HH.—Form more elongate, parallel, and depressed; punctures of pronotum much finer near front than behind.

I.—Puncturation of pronotum (especially near hind angles) more coarse, and subrugulose - - - - consors, Blackb.

II.—Puncturation of pronotum (especially near hind angles) less coarse and not rugulose semicaecus, Macl.

GG.—Elytral interstices only obsoletely crenulate.

H.—Size moderate (at least $1\frac{3}{4}$ l.); pronotum (viewed from side) longitudinally arched - - - coloratus, Blackb.

HH.—Size much smaller (less than $1\frac{1}{2}$ l.); pronotum (viewed from side) longitudinally flat - -torridus, Blackb.

CC.—Pronotum very closely and evenly punctulate (elytral interstices form very narrow carinae) - - walkeri, Blackb.

N.B.—I am unable to place A. (Ammoecius) obscurus, Macl., in the above table.

A. MONILIATUS, sp. nov.

Oblongus; sat opacus; niger, palpis rufis; capite confertim subtiliter vix aspere punctulato, antice emarginato, sutura clypeali nulla; prothorace transversim subquadrato, supra in disco (et hic subnitido) minus crebre punctulato (puncturis a basi antrorsum gradatim minoribus et minus crebre positis), latera versus crebre ruguloso, longitudinaliter subobsolete canaliculato, angulis anticis obtusis posticis dentiformibus, basi haud marginata; scutello elongato-triangulari; elytris 10-costatis (costis sub-

nitidis), interstitiis seriatim concinne granulatis, spina humerali bene definita; tarsorum articulo basali valde elongato.

Long. 2½ l. Lat. 1 l.

Differs from the other Australian Ataenii (known to me) with granulate elytra by, *inter alia*, its pronotum having a distinct longitudinal sulcus, and puncturation which on the disc is very far from being confluent (the interspaces of the punctures being subnitid and some of them being conspicuously larger in area than the adjacent punctures). This species seems to differ from all those described by Macleay as Ammoecii (some of which are, no doubt, Ataenii), inasmuch as they are all diagnosed as of smaller size and none of them are recorded to have granulated elytra.

N.W. Australia; sent by Mr. Froggatt.

A. KOEBELEI, sp. nov.

Oblongus; sat opacus; niger, palpis rufis; capite confertim subtilius ruguloso, antice late leviter emarginato, sutura clypeali fere nulla; prothorace transversim subquadrato, supra confertim (a basi antrorsum gradatim magis subtiliter) ruguloso, angulis omnibus obtusis, basi vix perspicue marginata; scutello sat elongato, triangulari; elytris 10-costatis (costis vix subnitidis), interstitiis seriebus granulorum binis instructis (seriei internae granulis minutis), spina humerali bene definita; tarsorum posticorum articulo basali valde elongato.

Long. 2⅕ l. Lat. 1 l. (vix).

The intervals between the raised lines on the elytra bear a series of conspicuous granules, and also a row of smaller and much less conspicuous granules. In this respect A. granulator, Har. (from New Guinea) resembles it, but *inter alia* that species is clothed with fulvous setae.

Queensland (taken by Mr. Koebele at Cairns).

A. (AMMOECIUS) OBSCURUS, Macl.

Harold (Ann. Mus. Gen., 1877, p. 58) assigns this species to Ataenius, and mentions it as having granulate elytra. Unfortunately he does not say on what ground he bases his identification, and it does not seem likely that he examined the type, which is presumably in the Australian Museum at Sydney.

Macleay, in describing the species, states that the elytra have wide striae "filled with shallow punctures." I cannot therefore accept Harold's statement as reliable, though I have no doubt he is right in calling A. obscurus an Ataenius, but there is no conclusive reason alleged for thinking that Macleay was wrong in attributing punctures, rather than granules, to the intervals between the elytral costae. I have before me several specimens of an Ataenius taken by Mr. H. J. Carter about 50 miles north of Sydney, which present all the few characters attributed by Macleay to A. obscurus (not sufficient evidence, I admit, for confident identification), except that they are a trifle smaller than the size quoted by the describer ($1\frac{3}{4}$ l. instead of 2 l). This species is near A. australis, Har., and falls beside it in my tabulation (*vide* supra). It differs, however, from australis not only in being smaller, but also in the disc of its pronotum being still more closely punctulate, and in the 3rd and 5th interstices of its elytra being very evidently less strongly carinate than the 2nd and 4th interstices.

A. IMPARILIS, sp. nov.

Oblongus; sat opacus; niger; palpis antennis tarsis et tibiis anticis plus minusve ferrugineis; capite confertim subtiliter aspero, antice emarginato, sutura clypeali sinuata; prothorace transversim subquadrato supra confertim aspere (postice quam antice minus subtiliter) punctulato, angulis anticis obtusis posticis rectis, margine pone angulos posticos late emarginato, basi haud marginata; scutello elongato-triangulari; elytris 10-costatis, costis 2^a fere nulla 4^a leviter elevata 6^a modica ceteris magis altis, interstitiis seriatim granulatis, spina humerali bene definita; tarsorum posticorum articulo basali valde elongato.

Long. $2\frac{1}{2}$ l. Lat. 1 l.

Very distinct from the other Ataenii, known to me by the sculpture of its elytra which is very remarkable and almost indescribable, owing to the alternate costae being more declivous on their external than on their inner face (but becoming normal close to the apex); consequently, if the elytra be looked at obliquely downward from the side, there appears to be, on the more distant elytron, no costa in the place where the 2nd costa might be expected, but a wide interval between the 1st and 3rd

bearing three rows of granules, a very feeble 4th costa, a 6th costa only slightly enfeebled, and the rest of the costae well defined; but on the nearer elytron (the external face of whose costae is towards the observer) the 2nd costae appears distinct, though feeble, the 4th appears not much enfeebled, and the rest all strongly elevated.

N. S. Wales; Clarence River (sent by Mr. Lea).

A. SPARSICOLLIS, sp. nov.

Subparallelus; sat elongatus; fere glaber; obscure rufo-piceus, capite antice prothoracis, lateribus palpis antennis pedibusque rufis; capite subtiliter aspero longitudinaliter strigato, antice emarginato; prothorace quam longiori fere ut 5 ad 3 latiori, subquadrato, supra in disco grosse inaequaliter (postice minus, antice magis, sparsim) punctulato, latera versus confertim ruguloso, longitudinaliter sulcato (sulco postice magis profundo), lateribus breviter setosis subtiliter crenulatis fere rectis, angulis anticis obtusis posticis fere rectis, margine pone angulos posticos late emarginato, basi haud marginata; scutello triangulari sat elongato; elytris crenulato-striatis, interstitiis carinatis, spina humerali breviter acuta; metasterno grosse sat aequaliter vix crebre punctulato; tarsorum posticorum articulo basali valde elongato.

Long. 2 l. Lat. $\frac{7}{10}$ l.

Allied to the S. Australian species which, I have no doubt, is A. australis, Har., but differing from it by being of somewhat narrower form and more reddish colour, and especially by the puncturation of its pronotum (which not only becomes finer towards the front of the disc but also much less close, whereas in the S. Australian species it becomes not only finer towards the front but also considerably closer), and by the distinct crenulation of the sides of that segment. In sparsicollis, also, the metasternum is less closely punctulate. In other respects the above description of sparsicollis applies also to the species that I regard as australis, Har.

Central Australia (Oodnadatta).

A. (AMMOECIUS) SEMICORNUTUS, Macl.

The description of this species is not sufficiently detailed for identification, but I have two examples from the original locality

(Gayndah) which bear the name on the authority of Mr. Masters, who is so remarkably accurate in his determinations that I have no doubt he is right in this case. The name seems to have been given with reference to a "very minute tubercle or tuberosity (on the back of the head on each side) which is extended in a raised line to the lateral border." This appears to be traceable in (at any rate most of) the Australian Ataenii, and is the line in which the subhorizontal narrow base of the head meets the declivous front part of the head ; in semicornutus it certainly appears a little more conspicuous than in some other species (*e.g.*, australis, Har.), and its inner end is a little more abrupt and tubercle-like, but does not seem to me to justify such a name as semicornutus. I have met with specimen in Central Australia which I cannot separate from those sent by Mr. Masters. The species is somewhat near A. australis, Har., and sparsicollis, Blackb., but is readily distinguishable from both by the lateral part of its pronotum (not opaque with dense shallow rugulosity but) nitid and bearing coarse deep puncturation, and by the disc of its metasternum devoid of punctures except in the extreme front. The puncturation of the disc of the pronotum is almost as in A. sparsicollis, Blackb.

A. TWEEDENSIS, sp. nov.

Minus angustus; minus parallelus; minus depressus; subnitidus fere glaber; piceo-niger vel rufo-piceus, antennis palpis pedibus et corpore subtus dilutioribus; capite (parte basali excepta) laevi vel vix subtilissime punctulato, antice emarginato; sutura clypeali nulla; prothorace quam longiori fere ut 4 ad 3 latiori, subquadrato, supra in disco inaequaliter vix crebre sat grosse (antice subtilius) punctulato, latera versus puncturis haud magis crebris et areis laevibus intermixtis, lateribus leviter arcuatis, angulis omnibus obtusis, basi infra superficiei planum marginata; scutello triangulari minus elongato; elytris crenulato-striatis, interstitiis sat latis minus (apicem versus magis perspicue) convexis, spina humerali parva; metasterni disco haud punctulato; tarsorum posticorum articulo basali valde elongato.

Long. 2 l. Lat. 1 l. (vix).

The prominent characters of this species are the absence of sculpture on the head (except some punctures across the base),

the sides of the pronotum with puncturation of the same kind as that of the disc and with unpunctured areas, the feeble humeral spines of the elytra, and the slight convexity of the elytral interstices. There is no true marginal carina on the dorsal surface of the pronotum, but the hind face of the prothorax (below the plane of the dorsal surface) projects as a ridge that from some points of view simulates a basal carina of the pronotum.

N. S. Wales; Tweed River (Mr. Olliff).

A. NUDUS, sp. nov.

Sat angustus, sat parallelus; sat depressus; sat nitidus; fere glaber; niger vel piceo-niger, pedibus dilutioribus, antennis palpisque rufescentibus; capite (parte basali excepta) vix manifeste punctulato, antice emarginato; sutura clypeali obsoleta; prothorace fere ut A. tweedensis, Blackb., sed quam longiori ut 3 ad 2 latiori; scutello ut A. tweedensis; elytris crenulato-striatis, interstitiis minus latis antice manifeste carinatis postice alte anguste carinatis, spina humerali parva; metasterni disco haud punctulato; tarsorum posticorum articulo basali valde elongato.

Long. $1\frac{9}{10}$ l. Lat. $\frac{7}{10}$ l.

Narrower, more parallel, and more depressed than the preceding A. tweedensis, Blackb.; the prothorax more transverse; and the elytral interstices narrower, in front a little more convex, and near the apex very much more convex. The elytral interstices, compared with those of the species referred to above as A. australis, Har., are in front much (but, near the apex, scarcely) less convex.

W. Australia; Pinjarrah (Mr. Lea).

A. GIBBUS, sp. nov.

Minus angustus; minus parallelus; sat convexus; minus nitidus; fere glaber; niger, antennis palpis pedibusque rufes centibus; capite (partibus basali et laterali exceptis) vix perspicue punctulato, antice emarginato; sutura clypeali vix manifesta; prothorace quam longiori ut 4 ad 3 latiori, subquadrato, supra inaequaliter vix crebre sat fortiter (antice paullo magis subtiliter) punctulato, lateribus leviter arcuatis, angulis omnibus obtusis, basi infra superficiei planum marginata; scutello triangulari

minus elongato; elytris striatis (striis leviter crenulatis), interstitiis modice latis antice modice convexis postice anguste carinatis, spina humerali parva; metasterni disco subtilissime sparsim punctulato; tarsorum posticorum articulo basali valde elongato.

Long. $1\frac{4}{5}$ l. Lat. 1 l.

Resembles O. tweedensis, Blackb., in form but is even wider and more convex; its surface is very manifestly less nitid; its pronotum considerably less coarsely punctulate; its elytral striae less strongly crenulate; its elytral interstices narrower and more convex; especially near the apex.

N. S. Wales; Hillgrove (Mr. Lea).

A. MACILENTUS, sp. nov.

Subparallelus; sat elongatus; minus convexus; fere glaber; subnitidus; niger, palpis antennis tarsisque ferrugineis; capite (parte basali excepta) fere laevi, antice emarginato, sutura clypeali nulla vel vix perspicua; prothorace quam longiori ut 7 ad 5 latiori, subquadrato, supra inaequaliter sat sparsim sat grosse (antice vix minus fortiter, latera versus crebre sat aequaliter) punctulato, lateribus leviter arcuatis, angulis omnibus obtusis, basi infra superficiei planum marginata; scutello triangulari modice elongato; elytris crenulato-striatis, interstitiis minus latis antice sat convexis postice anguste carinatis, spina humerali parva; metasterni disco sublaevi vel puncturis rarissimis impresso; tarsorum posticorum articulo basali valde elongato.

Long. 2 l. Lat. $\frac{9}{10}$ l.

Near A. nudus, Blackb., but readily distinguishable by the puncturation of its pronotum becoming close and even on the extra-discal portion.

N. S. Wales; Forest Reefs (Mr. Lea).

A. SPISSUS, sp. nov.

Minus angustus; minus parallelus; sat convexus; fere glaber; subnitidus; niger, clypei margine palpis antennis pedibusque rufis; capite postice subfortiter (latera versus crebre leviter) punctulato, antice emarginato; sutura clypeali haud perspicua; prothorace quam longiori ut 3 ad 2 latiori, subquadrato, supra sat aequaliter (basin versus magis grosse minus crebre) crebre sat

fortiter punctulato, lateribus leviter arcuatis, angulis omnibus obtusis, basi infra superficiei planum marginata; scutello triangulari minus elongato; elytris crenulato-striatis, interstitiis minus latis antice sat fortiter convexis postice sat anguste carinatis, spina humerali parva; metasterni disco fere laevi; tarsorum posticorum articulo basali valde elongato.

Long. $1\frac{1}{2}$ l. Lat. $\frac{3}{4}$ l.

In common with the preceding four species, this Ataenius has a hindward projecting ridge along the base of the prothorax, below the plane of the dorsal surface, which, if the prothorax is in contact with the base of the elytra, simulates a basal margin of the pronotum. In many species of Ataenius the corresponding ridge is (though not absolutely wanting) much less defined and conspicuous. The present insect is of convex (and but little parallel) form, similar to that of A. tweedensis, Blackb., and A. gibbus, Blackb., from both of which it differs *inter alia* by the considerably closer puncturation of the disc of its pronotum. That segment is somewhat similarly punctulate in the species mentioned above as A. australis, Har., but differs by its well-defined longitudinal sulcus.

N. Queensland (Mr. Koebele).

A. CONSORS, sp. nov.

Sat angustus; sat parallelus; sat convexus; fere glaber; subnitidus; niger, clypei margine palpis antennis pedibusque rufescentibus; capite postice punctulato, antice et latera versus subtilius minus crebre granulato, antice emarginato; sutura clypeali nulla; prothorace quam longiori ut 4 ad 3 latiori, supra sat aequaliter (basin versus fortiter minus crebre) crebre vix fortiter punctulato, lateribus leviter arcuatis, angulis omnibus obtusis, basi infra superficiei planum marginata; scutello triangulari, modice elongato; elytris crenulato-striatis, interstitiis sat angustis antice sat convexis postice carinatis angustis, spina humerali parva; metasterni disco puncturis non nullis sat grossis impresso; tarsorum posticorum articulo basali valde elongato.

Long. $1\frac{9}{10}$ l. Lat. $\frac{9}{10}$ l. (vix).

The puncturation of the pronotum is not much different in distribution from that of the species referred to above as A. australis, Har., but it is conspicuously less coarse and becomes

more suddenly finer about the middle. The absence of a longitudinal sulcus and the much less cariniform elytral interstices *inter alia* separate it widely from australis. Its much more parallel form distinguishes it from several of the preceding species, and the much closer puncturation of its pronotum from others. Its nearest ally is A. goyderensis, Blackb., from which it differs by the granulation of its head much finer and not extending to the median portion of the disc, and by the puncturation of its pronotum considerably closer and finer in the front part.

N. Queensland (Mr. Koebele).

A. (AMMOECIUS) SEMICOECUS, Macl.(?).

This name appears to be a misprint for "semicaecus." I have before me a species from N.W. Australia which I am disposed to identify with it, since it agrees with the description fairly well, and is from the same region. It differs from the description in the tendency of the sides of the head to granulation, in the hind angles of the prothorax being more obtuse than I should expect from the phrase "nearly square," and in the elytra not being conspicuously more "brownish" than tne pronotum. It would not, however, be safe to treat this species as distinct from semicoecus, especially as it agrees with the description in its pronotum being "finely punctulate," more finely and smoothly, indeed, than in any of its immediate allies. Except for this last-named character the insect is very close to A. consors, Blackb.

A. COLORATUS, sp. nov.

Minus angustus; modice parallelus; modice convexus; fere glaber; minus nitidus; niger palpis antennis pedibus elytrorumque apice ferrugineis; capite postice punctulato, antice et latera versus subtilius plus minusve perspicue granulato, antice emarginato; sutura clypeali nulla; prothorace quam longiori ut 4 ad 3 latiori, subquadrato, supra sat aequaliter sat crebre vix fortiter (postice magis fortiter, paullo minus crebre) punctulato, lateribus leviter arcuatis, angulis omnibus obtusis, basi infra superficiei planum marginata; scutello triangulari minus elongato; elytris striatis (striis leviter crenulatis), interstitiis minus latis antice sat convexis postice angustis manifeste

carinatis, spina humerali parva; metasterni disco vix perspicue punctulato; tarsorum posticorum articulo basali valde elongato.

Long. $1\frac{9}{10}$ l. Lat. $\frac{9}{10}$ l.

Somewhat intermediate in form between A. gibbus, Blackb., and its allies, and the more parallel depressed species. The puncturation of the pronotum is much like that of the species I take to be A. australis, Har., but is somewhat more rugulose and less close near the hind angles. The reddish apical region of the elytra seems to be constant. The crenulations of the elytral striae are feebly impressed, as in A. gibbus, from which species it is readily distinguishable by, *inter alia*, its much less smooth head and the much closer and more even puncturation of its pronotum. It is not unlike A. torridus, Blackb., structurally, but differs by, *inter alia*, its very much greater size, and its head more or less granulate and not distictly punctulate. From A. goyderensis, Blackb., it differs by, *inter alia*, the much more feeble crenulation of its elytral striae.

W. Australia.

A. WALKERI, sp. nov.

Minus angustus; modice parallelus; minus convexus; fere glaber; opacus; niger, palpis antennis pedibusque ferrugineis; capite confertim subtilissime punctulato et longitudinaliter strigoso, antice emarginato; prothorace subquadrato, quam longiori fere ut 3 ad 2 latiori, supra aequaliter confertim subtiliter punctulato, lateribus vix arcuatis, angulis omnibus obtusis, basi haud marginata; scutello triangulari minus elongato; elytris sulcatis, sulcis vix perspicue crenulatis; interstitiis cariniformibus, spina humerali parva; metasterni disco subfortiter minus sparsim punctulato; tarsorum posticorum articulo basali valde elongato.

Long. $1\frac{1}{5}$ l. Lat. $\frac{1}{2}$ l.

The extremely fine close and even puncturation of the pronotum of this very small species distinguishes it readily from all the other Australian Ataenii known to me.

N. Territory of S. Australia (Mr. J. J. Walker).

Euparia.

The following species must, I think, be referred to this genus. I regret that I have not in my extra-Australian collec-

tion a specimen of an already described Euparia for comparison. Lacordaire speaks of the genus as consisting of two divisions, the second of which appears to have been subsequently separated by Harold as the aggregate on which he founded Ataenius. Lacordaire distinguishes his second division of Euparia [of which, he says, the type is E. (Aphodius) stercorator, Fab.] from the first by the apex of the frontal dilatation on either side of the head being obtuse (acute in the first division), by the base of the prothorax being gently rounded (very sinuate near the hind angles, in the first division), and by the absence of a strongly developed humeral spine of the elytra. Harold (Ann. Mus. Gen., 1877, p. 97) mentions some other characters, speaking of Ataenius as "perfectly distinct from Euparia by its prothorax not depressed on the sides, by its legs not elongated, and by its straight posterior tibiae." The insect before me presents all the characters indicated above as distinctive of Euparia, and therefore I have no doubt of its being a member of that genus.

E. OLLIFFI, sp. nov.

Elongata; sat parallela; modice convexa; fere glabra; sat nitida; piceo-nigra, antennis ferrugineis; capite crebre subtiliter subaspere punctulato, antice late leviter emarginato; sutura clypeali haud perspicua; prothorace quam longiori ut 10 ad 7 latiori, subquadrato, supra sat aequaliter crebre dupliciter (subtiliter et rugulose subgrosse) sat aequaliter punctulato, marginibus (antice quam postice magis late) manifeste explanatis, lateribus antice sinuatim sat rectis (ante angulos posticos emarginatis), angulis anticis obtusis posticis retrorsum prominentibus, basi ad latera fortiter sinuata; scutello anguste elongato; elytris sat fortiter sulcatis, sulcis sat obsolete crenulatis, interstitiis punctulatis sat angustis cariniformibus, spina humerali sat magna; metasterni disco crebre fortiter punctulato; tarsorum posticorum articulo basali modice elongato; tarsis sat robustis.

Long. $2\frac{1}{2}$ l. Lat. 1 l.

This species has a quite remarkable superficial resemblance to a liliputian Cryptodus caviceps, Westw. It was given to me many years ago by the late Mr. A. S. Olliff.

N. S. Wales (Tweed R.).

Psammodius.

This genus has not, to my knowledge, been previously recorded as Australian, although it is of wide distribution in other countries. Mulsant (Lamell. d. France) proposed to break it up into four genera, but Erichson subsequently declined to accept these aggregates as more than sub-genera, and in this he was followed by the Baron de Harold. None of the Australian species known to me can be regarded as typical examples of any of these sub-genera, though one of them comes very near to the sub-genus Psammodius, the only difference I can find consisting in the extreme feebleness (almost absence) of sulcation on the pronotum. The other species differ from the sub-genus Psammodius by their pronotum not laterally fringed with setae, from the sub-genus Pleurophorus by the basal joint of their hind torsi shorter than the apical spine of the hind tibiae, and from Platytomus by their hind femora not more feeble than the front femora. The characters just mentioned would seem to associate them with Diastictus, but they have not the extremely small claws of that aggregate. Probably they are not far from P. indicus, Har. (from the Malay Archipelago), which is mentioned by its author as not referable to any named sub-genus, although the almost absence of sulci on the pronotum perhaps indicates a wide divergence; in respect of this character they would seem to be near P. laevicollis, Klug., which Harold places near P. indicus. One of these Psammodii, I have already described under the name zietzi, but by some oversight I attributed it to Ataenius, which I now see is certainly not its right place.

In assigning these insects to Psammodius, it seems desirable tc say that I have not succeeded in making a satisfactory observation of the mouth organs, and that I am not sure of the outer lobe of the maxillae being denticulate at the apex. The species before me differ from Aphodius, Ammoecius, &c., in having the top of the front declivity of the elytra defined, and from Euparia, Ataenius, and Rhyssemus by their hind tibiae strongly dilated towards the apex. Their hind femora of widely oval form (with the front outline very strongly arched), and the strongly granulate head with its clypeus not distinguished from the general surface, are quite in accordance with Psammodius, as

also the narrow elongate scutellum. The apex of the pygidium, when the abdomen is not shrunk or unduly extended, is distinctly visible but only to a small extent. The length of the basal joint of the hind tarsi varies (as in the acknowledged sub-genera of Psammodius) but is never greater (as it is in Ataenius, etc.) than the width of the apex of the hind tibiae. The only character that causes me any hesitation in placing the following species in Psammodius is the extreme feebleness of the inequalities on the surface of their pronotum, but (as noted above) there is already at least one species of Psammodius (recognized by Harold) in which the sulci of the pronotum are more or less obsolete. The eyes are normal, and very distinctly granulate.

Ps. AUSTRALICUS, sp. nov.

Ovatus; sat latus; convexus; sat nitidus; sat glaber (sed prothorace setulis fimbriato; rufo-brunneus; capite granulato, antice late subemarginato; prothorace quam longiori ut 3 ad 2 latiori, supra grosse minus inaequaliter minus sparsim (sed prope latera sparsim) punctulato, latera versus transversim (pone marginem anticum leviter, prope medium obsolete) breviter sulcato, lateribus arcuatis, angulis omnibus obtusis, basi haud marginata; scutello triangulari modice elongato; elytris crenulato-striatis, interstitiis vix convexis vix perspicue punctulatis, spina humerali minuta; metasterni disco laevi; tarsorum posticorum articulo basali quam tibiae latitudo breviori.

Long. $1\frac{3}{5}$ l. Lat. $\frac{4}{5}$ l (vix).

N. S. Wales (from Mr. Lea).

Ps. OBSCURIOR, sp. nov.

Subovalis; minus latus, sat convexus; sat nitidus; fere glaber; nigro-piceus, palpis antennis capite antice pedibusque rufis; capite granulato, antice emarginato; prothorace quam longiori fere ut 4 ad 3 latiori, supra in parte postica longitudinaliter sulcato, acervatim grossissime punctulato, latera versus transversim (pone marginem anticum profunde, prope medium vix perspicue) sulcato, lateribus parum arcuatis, angulis omnibus obtusis, basi haud marginata; scutello triangulari sat anguste elongato; elytris striatis, striis profunde crenulatis, interstitiis sat angustis sat con-

vexis vix perspicue punctulatis, spina humerali modica; metasterni disco laevi; tarsorum posticorum articulo basali quam tibiae latitudo breviori.

Long. $1\frac{2}{5}$–$1\frac{3}{5}$ l. Lat. $\frac{3}{5}$ l.

Decidedly narrow and elongate for a Psammodius. The sulcation of the pronotum is not so obsolete as in the other two Australian species that I attribute to the genus. The puncturation of the pronotum is extremely coarse. In some examples the elytra are more or less decidedly brown.

S. Australia; also W. Australia (from Mr. Lea).

TABULATION OF AUSTRALIAN PSAMMODII.

A.—Pronotum fringed with setae - - australicus, Blackb.
AA.—Pronotum not setulose.
B.—Length of basal joint of hind tarsi considerably less than width of apex of tibia - - - - - - obscurior, Blackb.
BB.—Length of basal joint of hind tarsi scarcely less than width of apex of tibia - - - - - - - zietzi, Blackb.

Saprosites.

This genus has not been previously recorded as Australian, although at least one Australian species belonging to it has been described as a member of a closely allied genus. I have in my extra-Australian collection a specimen of S. pygmaeus, Har., named by Dr. Sharp, and therefore can be quite confident in referring the following four species to Saprosites, as they are all undoubtedly congeneric with S. pygmaeus. They differ essentially from all the other Aphodiides known to me by the structure of the mesosternum, which is not declivous between the intermediate coxae but continues the plane of the metasternum. This segment, however, varies remarkably in its structure, according to the species, in other respects; the median line in some species being a narrow longitudinal carina (as in S. pygmaeus); in other species the mesosternum being, between the intermediate coxae, a much wider and non-cariniform process which is either nearly flat or obtusely convex. The hind tibiae

are short and strongly dilated towards the apex, but not transversely carinate. The top of the front declivity of the elytra is not distinctly margined, but is defined and abrupt [as compared with the same in (*e.g.*) Aphodius].

My Ataenius mendax must be transferred to this genus. I have received from Mr. Lea some specimens under the name Ammoecius nitidicollis, Macl., which also appertain to Saprosites. Macleay's description mentions no character indicating the genus of his species and is so brief that it might apply to any one of several Ataenii, etc., before me. Presumably, however, Mr. Lea has compared them with Macleay's type and considered them identical, though it must be noted that I have seen a different species (a Saprosites, however) in Mr. Griffiths' collection, which their owner tells me Mr. Lea regarded also as S. nitidicollis, Macl. As, however, the specimens Mr. Lea sent to me agree better with Macleay's description than does that shown me by Mr. Griffith (the head in the latter being quite strongly punctulate), I think it is best to claim Macleay's name for the former and to treat it as correctly named by Mr. Lea.

The Australian species which I refer to Saprosites do not seem to have strong external sexual characters. In the three species of which I have both sexes [mansuetus, Blackb.; nitidicollis, Macl. (?); and mendax, Blackb.] I can find no sexual characters on the head or in the armature of the front tibiae, but the sexes differ in the structure of the abdomen; the pygidium in one sex (probably male) being vertical and more convex, while in the other sex it is flatter, and sufficiently deflected under the insect to be visible when the specimen is laid on its back. In the former sex the ventral sutures are strongly sinuous with their front margin multidenticulate; in the latter a little (nitidicollis and mendax) or much (mansuetus) less so.

S. MANSUETUS, sp. nov.

Minus elongatus; sat parallelus; minus convexus; fere glaber; sat nitidus; piceus, nonnihil rufescens, palpis antennis pedibusque plus minusve dilutioribus; capite subtilissime vix crebre punctulato, antice late leviter emarginato; sutura clypeali haud perspicua; prothorace subquadrato quam longiori fere ut 4 ad 3 latiori, supra dupliciter (subtiliter et fortiter) subacervatim

punctulato, lateribus leviter arcuatis, angulis omnibus obtusis, basi ad latera manifeste (in medio haud) marginata; scutello triangulari minus elongato; elytris fortiter crenulato-striatis, interstitiis minus convexis subtilissime punctulatis, dente humerali parvo; metasterni disco subtiliter nec crebre punctulato; mesosterno inter coxas intermedias longitudinaliter anguste carinato; tarsorum posticorum articulo basali quam tibiae latitudo subbreviori.

Long. $1\frac{3}{5}$ l. Lat. $\frac{3}{5}$ l. (vix).

Not unlike S. pygmaeus, Har., and with the mesosternum of similar structure. It is, however, *inter alia* a larger species of darker colour, and having the pronotum very much more coarsely punctured.

W. Australia; Donnybrook (Mr. Lea).

S. STERNALIS, sp. nov.

Minus elongatus; sat parallelus; minus convexus; fere glaber; sat nitidus; rufus; capite subtilissime vix crebre punctulato, antice late leviter emarginato; sutura clypeali nulla; prothorace subquadrato, quam longiori fere ut 4 ad 3 latiori, supra dupliciter (subtiliter et fortiter) subacervatim punctulato, lateribus leviter arcuatis in parte antica sat late deplanatis, angulis omnibus obtusis, basi haud marginata; scutello triangulari modice elongato; elytris fortiter crenulato-striatis, interstitiis minus convexis laevibus, dente humerali sat magno; metasterni disco laevi; mesosterno inter coxas intermedias laevi longitudinaliter late obtuse convexo; tarsorum posticorum articulo basali quam tibiae latitudo sublongiori.

Long. $1\frac{1}{2}$ l. Lat. $\frac{3}{5}$ l. (vix).

Differs from the preceding (S. mansuetus), *inter alia*, by its mesosternum not carinate between the intermediate coxae and by the lateral margins of its pronotum being very conspicuously flattened in their front part.

N. S. Wales; Tweed R. (Mr. Olliff).

S. MENDAX, Blackb.

Modice elongatus; sat parallelus; minus convexus; fere glaber; sat nitidus; piceus, pedibus dilutioribus, palpis antennis-

que rufis; capite crebre minus subtiliter punctulato, antice late leviter emarginato; sutura clypeali nulla; prothorace subquadrato, quam longiori fere ut 4 ad 3 latiori, supra dupliciter (subtiliter et sat fortiter) vix acervatim punctulato, lateribus leviter arcuatis in parte antica summa leviter dilatatis, angulis anticis obtusis posticis obtuse dentiformibus, basi infra superficiei planum marginata; scutello triangulari modice elongato; elytris fortiter crenulato-striatis, interstitiis minus convexis sublaevibus dente humerali sat magno; metasterni disco subcrebre minus subtiliter punctulato; mesosterno inter coxas intermedias punctulato longitudinaliter late subplanato; tarsorum posticorum articulo basali quam tibiae latitudo sublongiori.

Long. $1\frac{3}{5}$ l. Lat. $\frac{3}{5}$ l.

As this insect was originally described as an Ataenius, and characters were omitted that distinguish it from the other Australian series of Saprosites (then unknown to me), I have thought it well to re-describe it. I may add that, since I wrote the original description, I have taken in Tasmania examples of a Saprosites in which the puncturation of the head is very evidently finer, but, as I cannot find any other definite characters to distinguish them from S. mendax, it seems best to regard them as representing a local form of that species. I have also seen what I believe to be the same species, in Mr. Griffith's collection, of a uniform ferruginous colour.

Victoria; N. S. Wales; Tasmania.

S. NITIDICOLLIS, Macl. (?).

The species mentioned above as probably this insect is readily distinguished from S. mansuetus, Blackb., by its mesosternum wider and non-carinate between the intermediate coxae, from S. sternalis, Blackb., by the very distinct fine puncturation of its meta- and meso-sterna, and from S. mendax. Blackb., by the hind angles of its prothorax not outwardly prominent.

The following table shows the characters by which the four Australian species that I refer to this genus may be distinguished. *inter se.*

A.—Mesosternum between coxae narrow and
cariniform - - - - - - mansuetus, Blackb.

AA.—Mesosternum between coxae wide, and flattish or obtusely convex.
  B.—Sterna non-punctulate - - - sternalis, Blackb.
  BB.—Sterna conspicuously punctulate.
    C.—Hind angles of prothorax outwardly prominent - - - - mendax, Blackb.
    CC.—Hind angles of prothorax not outwardly prominent - - - nitidicollis, Macl.?

Saprus (gen. nov., APHODIIDARUM).

Palpi labiales breves, maxillares modici (horum articulo ultimo quam ceteri longiori); mandibuli labrum excedentes; labrum apertum transversum; caput sat breve, sat convexum, antice vix emarginatum; oculi modici, perspicue sat subtiliter granulati; antennae 9-articulatae; prothorax transversus fere aequalis convexus; scutellum modicum, minus angustatum; elytra elongata, parallela, superficie dorsali antice bene definita nec margine elevata instructa, humeris dentatis; pedes sat elongati; pedum posticorum femora oblongo-ovalia, tibiis a basi ad apicem sat aequaliter sat fortiter dilatatis in margine externo denticulatis, tarsis sat elongatis (articulo basali sat cylindrico, quam sequentes 3 conjuncti et quam tibiae spina apicalis vix breviori); pygidium elytris haud plane tectum; coxae anticae contiguae, intermediis late distantes; mesosternum fere horizontale, inter coxas intermedias longitudinaliter tricarinatum.

It is impossible for me to describe the following very interesting species without giving it a new generic name, although I am very chary of proposing new genera in groups whose existing genera are known to be usually of wide distribution; since only a specialist in such a group can feel any confidence that he may not be re-naming some genus founded on a recently discovered species in some distant land. I am unwilling, however, to postpone the record of this species, and feel fairly sure that it cannot be placed in any genus known to Australasia or the Malayan regions. Its protruded labrum and mandibles associate it with Aegialia, with which genus, however, it agrees in scarcely any other structural character that is distinctive among the Aphodiides. Lacordaire, in his notes on Aegialia, states that there are some

species of more or less elongate form which Erichson transferred from Psammodius to Aegialia on account of their having the labrum and mandibles of the latter. Lacordaire does not particularize the species, nor does he mention where Erichson's note is to be found, nor can I find it in any work of Erichson's that I possess. Probably P. cylindricus, Eschsch, from the Aleutian Islands, is one of those referred to. I hardly think it possible, however, that the species described below can be congeneric with them, as it is unimaginable that Erichson would have referred it to Aegialia in spite of its elongate form, and if he had done so he would certainly have been in error. It has the facies of Saprosites, which it resembles in most of its characters.

S. GRIFFITHI, sp. nov.

Elongatus; parallelus; minus convexus; fere glaber; sat nitidus; piceus, palpis antennis pedibusque dilutioribus; capite crebre minus subtiliter punctulato; sutura clypeali perspicua; prothorace quam longiori ut 5 ad 4 latiori ab apice retrorsum leviter angustato, supra vix crebre (basin versus fortiter, antrorsum gradatim magis subtiliter) punctulato, postice longitudinaliter leviter late impresso, lateribus leviter arcuatis prope basin sat abrupte sinuatis, angulis anticis subprominulis posticis rectis, basi haud marginata; elytris sat fortiter crenulato-striatis, interstitiis convexis vix perspicue punctulatis, dente humerali modico; metasterni disco grosse inaequaliter punctulato.

Long. 2 l. Lat. $\frac{7}{10}$ l.

The deep median sulcus of the metasternum, which is present in all the species known to me of Saprosites (but which does not seem to vary sexually nor in a manner available for specific characters), becomes in this insect an oval excavation very coarsely punctulate at the bottom. I do not find in the specimens before me any characters likely to be sexual. The front tibiae are tridentate externally (as in Saprosites) and the ventral sutures are normal, without denticulation. The pygidium does not differ materially from that of the sex of Saprosites, which I regard as the female. Probably I have not seen the male of this insect.

Tasmania (Mr. Griffith).

Hybosorides.

This group (Lacordaire's 4th tribe) of the sub-family Coprides agrees with the Aphodiides in having two spines at the apex of the hind tibiae, but differs from the Aphodiides, *inter alia*, in having 10-jointed antennae, with the basal joint of the club cupuliform (the Aphodiides having 9-jointed antennae with the basal joint non-cupuliform). So far as I know it is represented in Australia by a single genus only.

Phoeochrous.

Of this genus a single species P. (Silphodes) emarginatus, Cast., has been reported by Harold to have been found in North Queensland, and Macleay described, under the name Silphodes hirtipes, an insect (also from Queensland) which appears to be a Phoeochrous. I have before me a considerable number of specimens from various localities in Queensland which seem to be certainly the insect described by Macleay, and the question suggests itself whether they are distinct from P. emarginatus. I am inclined to regard them as distinct, although I have not access to Castelnan's description. Harold, however, states that P. (Silphodes) indicus, Westw., and sumatrensis, Westw., are both identical with emarginatus, and Westwood's descriptions under those names do not appear to fit satisfactorily the Queensland specimens that I have mentioned. Nevertheless, the descriptions are very brief, and I cannot say that they specify any one character (appearing in both descriptions) that is absolutely irreconcilable with the identity of P. hirtipes. The most obvious inconsistency between it and Westwood's descriptions is that the latter call the head in sumatrensis, and the pronotum in indicus, "tenuissime punctato," which is not the case with either of those segments in hirtipes (its head, especially, being in both sexes quite strongly punctulate). Westwood's phrase, however, may have been a little exaggerated in respect of the insects before him; and so also, perhaps, with regard to the other small discrepancies that I notice. In P. hirtipes all the claws of the male are much more robust than those of the female, and are appendiculate.

In Masters' Catalogue a second genus (Coelodes) of the Hybosorides is enumerated as Australian, but Harold has pointed out that the species attributed to it (bimaculatus, Macl.) is in reality a Liparochus, and therefore not a Hybosorid.

[NOTE.—The author wishes it to be stated that names which are genitives of proper nouns were written with initial capitals by him, but were altered on the responsibility of the Editor. The author also objects to the non-use of diphthongs, and the use of Roman type for scientific names mentioned in the body of the paper.—THE EDITOR.]

Art. V.—*Tabulated List of the Fossil Cheilostomatous Polyzoa in the Victorian Tertiary Deposits.*

By C. M. MAPLESTONE.

[Read 9th June, 1904.]

In compiling this list of the fossil Cheilostomatous Polyzoa found in the Victorian Tertiary deposits, I have followed Dr. MacGillivray's classification as given in his "Monograph of the Tertiary Polyzoa of Victoria."[1] In addition to my own observations I have included Dr. MacGillivray's records in his monograph, Mr. Waters' in the Q.J.G.S. for 1881, *et seq.*, and Mr. Mulder's in the "Geelong Naturalist" for March, 1904, distinguishing Dr. MacGillivray's records by an *, Mr. Waters by a †, and Mr. Mulder's by a ‡. These records are, however, inserted only in cases where I have not observed the species in the different localities, and I have not deemed it necessary to indicate their records where they are the same as mine. I would here note that Dr. MacGillivray, in his records of the fossil species occurring in the Muddy Creek deposits (inserted in column 6), did not discriminate between the upper and lower beds, but I have included them so as to make the list as complete as possible, and also those of Mr. Waters from the same locality for the same reason. My records in that column are of specimens from the lower beds.

The total number of species recorded is 466, of which 125, or 28 per cent., are also living, though not all in Australian waters. The following is a summary of a comparison of the fossil and recent species.

The single species of Liriozoidae and Bigemellariidae are not found living. Of the 79 species of Catenicellidae recorded as fossil, 10 are also living in Victoria, one in South Africa, and one in the South Atlantic. Of Calwelliidae there is only one fossil species, and that is different from the recent ones. In the Cellulariidae there are 15 fossil species, 3 of which are living in Australia. There is only one fossil species of Bicellariidae; it is

1 Trans. Roy. Soc. Vic., vol. iv., 1895.

not recorded as living. There are 23 fossil species of Cellariidae, 3 of which are living in Australia, and one in the North Atlantic. There is only one fossil species of Flustridae, which is also living in Australia. There are 74 species of Membraniporidae, 23 of which are living, chiefly in Australian and South Pacific waters, one is found in the Mediterranean, one in the Canaries and Florida, one in the Falkland Islands and Kerguelen Island, and one ranges from Australian to European seas. There are 7 fossil species of Steganoporellidae, 3 of which are recorded as living, one on the coast of South America, Florida, New Zealand and Australia; another in Tahiti and Torres Straits, and another in Australia, New Zealand and Japan. None of the 8 fossil species of Microporidae are recorded as living. Of Cribrilinidae 16 species are recorded as fossil, one of which is living in Victoria, one in Bass Straits, one in European Seas, and one is cosmopolitan. There are 4 fossil species of Hiantoporidae, one of which is living in Victoria. Of Microporellidae 18 are found fossil and 9 of them are living, chiefly in Australian waters, but one extends to Florida, and two are cosmopolitan.

The family Lepraliidae is represented by 46 fossil species, two of them are found living in New Zealand, and six in Australian seas, two of which also occur in northern seas, and one occurs in the North Atlantic only. There are 55 species of Schizoporellidae, 15 of which are found in Australian seas, one of which also occurs in northern seas, one is cosmopolitan, one occurs in Patagonia, and one in China. Of the others, one is living in European seas, one in the North Pacific, and one in New Guinea. Of Smittiidae there are 65 fossil species, 20 of which are found living, 14 of them in Australian seas, 3 of which are also living in the northern hemisphere, 3 are living in the northern seas only, one in the Phillipine Islands, and one in Patagonia and the Falkland Islands. There are two fossil species of Tubucellariidae, one of which is living in Australian seas. In Prostomariidae the only species is a fossil one. There are 23 species of Celleporidae, 7 of which are also living on the Australian coast, one of which is also found in Florida. There are 25 fossil species of Reteporidae, 10 of them are living, 9 in the Australian seas, one of which is also found in Florida, but one is found only in European seas.

The almost purely Australian family Catenicellidae is very numerously represented, 79 species being recorded, and the number would no doubt be still further increased if a more diligent search were made for them; though it is surprising that so many specimens have been already found when their minuteness is considered, for the material I have received from several deposits had already been washed and cleaned, and the Catenicellidae had consequently vanished; this will account for their not being recorded from some of the localities. The fossil Cellariidae are also more numerous than the recent forms, and the Membraniporidae, Lepraliidae, Schizoporellidae and Smittiidae are also very largely represented. The Calwelliidae, Cellulariidae, Bicellariidae and Flustridae, being free growing and only slightly calcified, occur much less frequently in the deposits than do the more highly calcified and encrusting forms. The number of Celleporidae are probably much greater than is recorded, because their nature is such that, although specimens can be assigned to that family, it is in comparatively few cases they are sufficiently well preserved to permit of definite description.

Fossil Species now Living in America and Africa.

Catenicella taurina, Busk, South Africa.
Vittaticella sacculata, Busk, South Atlantic.
Cellaria biseriata, Map., North Atlantic.
Amphiblestrum annulus, Manz., sp., Falkland I. and Kerguelen I.
Cupularia canariensis, Busk, Canaries and Florida.
Farcimia oculata, Busk, Florida.
Thalamoporella rosieri, Aud., sp., S. America, Florida.
Escharipora stellata, Smitt, Florida.
Lepralia mucronata, Smitt, North Atlantic.
L. pertusa, Esper., North America, Europe.
Schizoporella phymatopora, Reuss, North Pacific.
S. ridleyi, McG., Patagonia.
Porella concinna, Busk, North America and Europe.
Smittia nitida, Verrill, Africa, North America and Mediterranean.
Aspidostoma crassum, Hincks, Patagonia, Falkland I.
Cellepora albirostris, Smitt, sp., Florida.

Fossil Species now Living in Northern Seas and Pacific Ocean.

Membranipora bidens, Busk, sp., Mediterranean.
Membranipora intermedia, Kirkpatrick, Torres Straits.
Membranipora lineata, L., Northern seas.
Membranipora macrostoma, Reuss, Phillipines.
Lunulites guineensis, Busk, New Guinea.
Steganoporella lateralis, McG., Tahiti and Torres Straits.
Steganoporella magnilabris, Bk., Japan.
Membranipora nitida, Johnston, European seas.
Cribrilina radiata, Moll., sp., Cosmopolitan.
Microporella ciliata, Linn., sp., Cosmopolitan.
Microporella malusii, Aud., sp., Cosmopolitan.
Lepralia depressa, Busk, Northern seas.
Schizoporella auriculata, Hassall, European seas.
Schizoporella biaperta, Michelin, sp., Northern seas.
Schizoporella cecilii, Aud., sp., Cosmopolitan.
Bipora elegans, D'Orb., China.
Smittia collaris, Norm., European seas.
Smittia reticulata, J. McG., sp., Europe.
Mucronella porosa, Hincks., Phillipines.
Rhyncopora bispinosa, Johnst., sp., Europe.

Northern Seas and Pacific.

Palmicellaria skenei, Ell. and Sol., Northern seas.
Retepora beaniana, King, European seas.

Species.	1 Cape Otway.	2 Aire Coast.	3 Darriman's	4 Waurn Ponds.	5 Spring Creek.	6 Muddy Creek, Lower Beds.	7 Gellibrand.	8 Curdie's Creek.	9 Shelford.	10 Fyansford.	11 Griffins.	12 Filter Quarries.	13 Corio Bay.	14 Campbell's Point.	15 Mornington.	16 Mitchell River.	17 Flinders.	Other Localities.
Fam. LIRIOZOIDAE.																		
Gen. *Liriozoa*, Lamk.																		
L. laevigata, Waters sp. - -					5	6					11					16		
Fam. BIGEMELLARIIDAE.																		
Gen. *Bigemellaria*, McG.																		
B. pedunculata, McG. - -											11			14‡	15	16		
Fam. CATENICELLIDAE.																		
Gen. *Catenicella*, Busk.																		
C. acuminata, Map. - -														14‡		16		
C. acutirostris, Map. - -						6												
C. alata, Wy. Thompson - -				4†	5†	6		8†			11			14	15	16		Living; Victoria.
C. ampla, Waters - - -					5*	6		8†						14‡	15	16		
C. ampliata, Map. - - -											11			14‡				
C. auriculata, McG. - -						6*								14‡	15	16		
C. baccata, Map. - - -														14‡	15			
C. cincta, McG. - - -						6*								14‡	15	16		
C. conica, Map. - - -						6												
C. cribraria, Busk - - -						6*								14	15	16		Living; Victoria.
C. cribriformis, Waters - -					5†			8†										

Species.	Cape Otway. 1	Aire Coast. 2	Darriman's. 3	Waurn Ponds. 4	Spring Creek. 5	Muddy Creek, Lower Beds. 6	Gellibrand. 7	Curdie's Creek. 8	Shelford. 9	Fyansford. 10	Griffins. 11	Filter Quarries. 12	Corio Bay. 13	Campbell's Point. 14	Mornington. 15	Mitchell River. 16	Flinders. 17	Other Localities.
C. crux, McG. - - -						6					11			14	15	16		
C. daedala, McG. - - -						6*					11*			14‡	15	16		
C. dennanti, Map. - - -																16		
C. elegans, Busk - - -						6†		8†										Living; Victoria.
C. elegantissima, Map. - -														14‡	15			
C. elongata, McG. - - -						6					11			14‡	15*			
C. flexuosa, Waters - - -								8†										
C. halli, Map. - - - -											11			14‡				
C. hastata, Busk - - -				4†	5†	6					11			14	15	16		Living; Victoria.
C. hiulca, Map. - - -						6												
C. intermedia, McG. - -						6					11			14‡	15	16		Living; Australia.
C. atifrons, McG - - -						6					11			14‡	15			
C. lineata, McG - - -														14‡	15			
C. lunipora, McG. - - -														14‡		16*		
C. macgillivrayi, Map. - -						6												
C. marginata, Waters - -								8†						14‡	15	16*		
C. nobilis, McG. - - -														14‡		16		
C. nutans, Map. - - -														14‡	15			
C. orbicularis, Map. - -														14‡	15			
C. ovoidea, McG. - - -						6*					11			14‡	15	16		
C. papillata, Map. - - -						6								14‡				

Species.	Cape Otway. 1	Aire Coast. 2	Darriman's. 3	Waurn Ponds. 4	Spring Creek. 5	Muddy Creek, Lower Beds. 6	Gellibrand. 7	Curdie's Creek. 8	Shelford. 9	Fyansford. 10	Griffins. 11	Filter Quarries. 12	Corio Bay. 13	Campbell's Point. 14	Mornington. 15	Mitchell River. 16	Flinders. 17	Other Localities.
C. personata, Map. - - -															15			
C. porosa, McG. - - -						6*								14‡				
C. retroversa, McG. - - -						6					11			14‡				
C. spenceri, Map. - - -						6												
C. stricta, McG. - - -						6*								14‡				
C. taurina, Busk - - -					5†													Living; South Africa.
C. tenuis, McG. - - -						6					11				15	16		
C. ventricosa, Busk - - -					5†	6								14				Living; Victoria.
Gen. *Stenostomaria*, McG.																		
S. solida, Waters, sp. - -				4†		6		8†		10	11*			14‡	15	16		Fishing Point, Cape Otway.
Gen. *Strophipora*, McG.																		
S. bellis, Map. - - - -						6								14‡		16		
S. excavata, Map. - - -						6								14‡				
S. harveyi, Wy. Thom., sp. -				4†	5†	6				10	11			14	15	16		Nhill. Living; Bass Sts., and West Australia.
S. sulcata, Map. - - -						6												
Gen. *Vittaticella*, Map.																		

Species.	1 Cape Otway.	2 Aire Coast.	3 Darriman's.	4 Waurn Ponds.	5 Spring Creek.	6 Muddy Creek, Lower Beds.	7 Gellibrand.	8 Curdie's Creek.	9 Shelford.	10 Fyansford.	11 Griffins.	12 Filter Quarries.	13 Corio Bay.	14 Campbell's Point.	15 Mornington.	16 Mitchell River.	17 Flinders.	Other Localities.
V. cordata, Map. - - -						6												
V. dendrina, Map. - - -						6												
V. enormis, Map. - - -														14‡	15			
V. grandis, Map. - - -						6								14‡				
V. hannafordi, McG., sp. - -						6*					11			14‡				Living; Victoria.
V. insignis, McG., sp. - -						6					11			14‡	15*	16		
V. maculata, Map. - - -											11							
V. praetenuis, McG., sp. - -						6*								14‡				
V. rostrata, Map. - - -						6												
V. sacculata, Busk, sp. - -						6*								14‡				Living; South Atlantic.
V. speciosa, McG., sp. - -						6					11			14‡	15	16		
V. teres, McG., sp. - - -						6					11			14‡	15			
Gen. *Strongylopora*, Map.																		
S. ampullacea, Map. - -						6												
S. circumcincta, Waters, sp. -				4†	5†	6					11			14‡	15	16		
S. complanata, Map. - -						6												
S. cuneiformis, Map. - -															15			
S. expansa, McG., sp. - -						6*					11			14‡				
S. mamillata, McG., sp. - -						6*								14‡	15			
S. nitida, Map. - - -						6												

Species.	Cape Otway. 1	Aire Coast. 2	Darriman's 3	Waurn Ponds. 4	Spring Creek. 5	Muddy Creek, Lower Beds. 6	Gellibrand. 7	Curdie's Creek. 8	Shelford. 9	Fyansford. 10	Griffins. 11	Filter Quarries. 12	Corio Bay. 13	Campbell's Point. 14	Mornington. 15	Mitchell River. 16	Flinders. 17	Other Localities.
S. pulchella, Map. - - -						6					11			14‡	15	16		Living; Victoria.
S. tenuis, McG., sp. - -						6					11			14‡	15	16		
Gen. *Digenopora*, Map.																		
D. compta, Map. - - -														14‡	15	16		
Gen. *Costaticella*, Map.																		
C. escharoides, Map. - -															15			
Gen. *Microstomaria*, McG.																		
M. tubulifera, McG. - -						6												
Gen. *Claviporella*, McG.																		
C. angusta, Map. - - -						6								14‡				
C. longicollis, Waters, sp. -				4†	5†	6				10	11			14‡				
C. mariona ·, McG. - - -						6									15			
C. obliqua, McG. - - -														14‡	15*			
C. vespertilio, McG. - -						6					11				15*			
Gen. *Calpidium*, Busk.																		
C. morningtoniensis, Map. -															15			

Species.	1 Cape Otway.	2 Aire Coast.	3 Darriman's.	4 Waurn Ponds.	5 Spring Creek.	6 Muddy Creek, Lower Beds.	7 Gellibrand.	8 Curdie's Creek.	9 Shelford.	10 Fyansford.	11 Griffins.	12 Filter Quarries.	13 Corio Bay.	14 Campbell's Point.	15 Mornington.	16 Mitchell River.	17 Flinders.	Other Localities.
Gen. *Catenaria*, Busk.																		
C. tenuis, Map. - - -						6												
Gen. *Catenariopsis*, Map.																		
C. morningtoniensis, Map. -							7								15			
Gen. *Ditaxipora*, McG.																		
D. internodia, Waters, sp. -			3	4†	5†	6		8†			11			14	15	16		Fishing Point, Cape Otway.
Fam. CALWELLIIDAE.																		
Gen. *Calwellia*, Wy. Thom.																		
C. otwayensis, Map. - -	1	2																
Fam. CELLULARIIDAE.																		
Gen. *Menipea*, Lamx.																		
M. alternata, McG. - - -														14‡	15*	16		
M. biaviculata, Map. - -	1																	
M. bicellata, Map. - - -											11			14‡				
M. lineata, McG. - - -						6*								14‡				
M. retroversa, Map. - - -					5													

Species.	Cape Otway. 1	Aire Coast. 2	Darriman's. 3	Waurn Ponds. 4	Spring Creek. 5	Muddy Creek, Lower Beds. 6	Gellibrand. 7	Curdie's Creek. 8	Shelford. 9	Fyansford. 10	Griffins. 11	Filter Quarries. 12	Corio Bay. 13	Campbell's Point. 14	Mornington. 15	Mitchell River. 16	Flinders. 17	Other Localities.
Gen. *Cellularia*, Pallas.																		
C. triangulata, Map. - -																16		
Gen. *Scrupocellaria*, Beneden.																		
S. crenulata, McG. - - -						6*					11			14‡				
S. glomerata, Map. - - -																16		
Gen. *Caberea*, Lamx.																		
C. darwini, Busk - - -						6*								14‡				Living; Australia, New Zealand and Southern Ocean.
C. grandis, Hincks - - -											11*			14‡	15	16	17	Living; Australia.
C. morningtoniensis, Map. -														14‡	15			
C. rudis, Busk - - - -								8†										Living; Victoria.
Gen. *Canda*, Lamx.																		
C. fossilis, Waters - - -		2		4†		6*		8†			11	12		14	15	16	17	
C. inermis, McG. - - -						6*								14‡				
Gen. *Amastigia*, Busk.																		
A. acuminata, Map. - - -											11							

Species.	1 Cape Otway.	2 Aire Coast.	3 Darriman's.	4 Waurn Ponds.	5 Spring Creek.	6 Muddy Creek, Lower Beds.	7 Gellibrand.	8 Curdie's Creek.	9 Shelford.	10 Fyansford.	11 Griffins.	12 Filter Quarries.	13 Corio Bay.	14 Campbell's Point.	15 Mornington.	16 Mitchell River.	17 Flinders.	Other Localities.
Fam. BICELLARIIDAE.																		
Gen. *Bicellaria*, Blainv.																		
B. elongata, Map. - - -														14‡	15			
Fam. CELLARIIDAE.																		
Gen. *Cellaria*, Lamx.																		
C. acutimarginata, McG. - -			3	4	5	6				10	11			14	15	16		
C. angustiloba, Busk - -			3		5	6				10	11		13*	14‡	15*	16		
C. australis, McG. - -	1				5	6		8†	9	10				14‡	15	16	17	Murgheboluc. Living; Australia.
C. biaperta, Map. - - -						6								14‡				
C. biseriata, Map. - - -														14‡				Grice's Creek. Living; North Atlantic (Waters).
C. contigua, McG. - - -	1	2	3	4†	5	6		8†	9	10	11	12		14‡	15	16		Beaumaris, Murgheboluc, Nhill.
C. crassimarginata, Map. -										10								
C. cucullata, McG. - - -	1	2			5	6								14‡				
C. dennanti, McG. - - -	1	2			5	6								14‡				
C. depressa, Map. - - -									9					14‡				
C. enormis, Map. - - -		2				6								14	15	16	17	
C. gigantea, Map. - - -																16		
C. globosa, Waters - - -								8†							15	16		
C. gracilis, Busk - - -						6*				10	11			14‡	15	16		Living; Victoria.

Species.	Cape Otway. 1	Aire Coast. 2	Darriman's 3	Waurn Ponds. 4	Spring Creek. 5	Muddy Creek, Lower Beds. 6	Gellibrand. 7	Curdie's Creek. 8	Shelford. 9	Fyansford. 10	Griffins. 11	Filter Quarries. 12	Corio Bay. 13	Campbell's Point. 14	Mornington. 15	Mitchell River. 16	Flinders. 17	Other Localities.
C. grandis, Map. - - -	1																	
C. incudifera, Map. - -					5													
C. laticella, McG. - - -						6†		8†						14‡	15		17	
C. ovicellata, Stol. - - -	1																	
C. rigida, McG. - - -					5	6				10				14‡	15*	16*	17	Living; Victoria.
var. perampla, Waters -		2		4†										14‡				
C. robusta, Map. - - -					5									14‡				
C. tumida, Map. - - -	1															16		
Gen. *Melicerita*, Milne Ed.																		
M. elliptica, Map. - - -		2																
Fam. Flustridae.																		
Gen. *Craspedozoum*, McG.																		
C. roboratum, Hincks, ep. -				4†		6*								14‡				Living; Victoria.
Fam. Membraniporidae.																		
Gen. *Membranipora*, Blainv.																		
M. ambigua, McG. - - -	1													14‡	15*			
M. appendiculata, Reuss -																16		Living; New Zealand.
M. argus, D'Orb. - - -								8†										

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M. aviculifera, Map. - -		2																
M. bellis, Map. - - -						6								14‡				
M. bidens, Busk, sp. - -				4														Living; Mediterranean.
M. circularis, D'Orb. - -	1	2				6												
M. cochleare, McG. - - -											11*				15	16		
M. concamerata, Waters - -	1	2						8†										
M. concinna, McG. - - -						6				10					15	16		Fishing Point, Cape Otway.
M. cyclostomata, McG. - -						6*								14‡	15*			
M. delicatula, Busk - -														14‡		16		Living; Australia.
M. dennanti, Map. - - -																16		
M. depressa, McG. - - -					5			8†		10				14‡	15*	16		Belmont.
M. elliptica, McG. - - -						6*								14‡	15*	16		
M. fossa, McG. - - -				4										14‡				
M. geminata, Waters - -					5*	6		8†			11*			14‡	15	16	17	
M. globulosa, Map. - - -						6												
M. gregsoni, McG. - - -					5*	6				10	11					16		
M. intermedia, Kirkp. - -						6*								14‡				Living; Torres Straits.
M. ligulata, Map. - - -		2																
M. lineata, L. - - -								8†										Living; Australia (Waters), and Northern Seas.
M. longipes, Map. - - -						6									15			

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M. macrostoma, Reuss - -	1	2	3			6		8†		10	11*		13*	14‡	15*	16	17	Living; Phillipines & Australia.
M. marginata, McG. - -	1										11*			14‡	15*		17	
M. morningtoniensis, Map. -															15			
M. papyracea, McG. - -					5*													
M. perfragilis, McG. - -						6*												Living; Victoria.
M. porcellana, Map. - -						6												
M. profunda, McG. - -		2				6								14‡	15*	16		
M. radicifera, Hincks - -						6				10	11*			14‡	15	16	17	Living; Victoria.
M. regularis, Map. - -	1	2												14‡		16		
M. savartii, Aud. - - -						6*								14‡				Living; Australia.
M. sculpta, McG. - - -						6								14‡	15*	16		
M. spiculifera, Map. - -																16		
M. striata, McG. - - -					5					10	11			14‡	15	16		
Gen. *Amphiblestrum*, Gray.																		
A. annulus, Manzoni, sp. -	1					6								14‡		16*	17	Living; Falkland Islands, and Kerguelen Island.
A. arethusa, D'Orb., sp, - -				4†	5*	6								14‡				
A. bispinosum, Map. - -																16		
A. bursarium, McG. - -														14‡	15*			Living; Victoria.
A. concavum, Map. - -																16		

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A. coriense, McG. - - -										10			13*		15			
A. crassissimum, Map. - -												12		14‡				
A. cylindriforme, Waters, sp. -	1		3			6		8†						14‡	15	16	17	
A. moniliferum, Map. - -		2																
A. nitidum, Map. - - -		2																
A. occultatum, Waters, sp. -																16*		Living; New Zealand.
A. ovatum, Map. - - -		2																
A. permunitum, Hincks, sp. -						6*												Living; Victoria.
A. planulatum, Map. - -		2																
A. robustum, Map. - -												12						
A. sexspinosum, Map. - -	1	2															17	
A. simplex, McG. - - -						6*								14‡	15			
A. variabile, Map. - - -						6												
Gen. *Lunulites*, Lamk. -																		
L. biformis, McG. - - -	1													14‡		16		
L. canaliculata, McG. - -																		Lake Bullenmerri.*
L. guineensis, Busk - -								8†										Living; New Guinea.
L. parvicella, Ten. Woods, sp. -					5	6				10		12		14		16		Lake Bullenmerri,* Fishing Point, Cape Otway.

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L. rutella, T. Woods					5	6			9	10				14	15			Belmont, Bullenmerri,* Lake Gnotuk, Fishing Point, Cape Otway.
Gen. *Selenaria*, Busk.																		
S. bimorphocella, Map.																		Jimmy's Point. Living; South Australia.
S. concinna, T. Woods	1	2				6				10		12		14‡		16		Belmont, Beaumaris, Lake Gnotuk, Bullenmerri,* Gellibrand and living, South Australia.
S. cribrosa, Map.																16		
S. cupola, T. Woods	1	2			5	6							13*		15*			Birregurra,* Bullenmerri,* Belmont, Lake Gnotuk, Fishing Point, C.O.
S. hexagonalis, Map.																		Jimmy's Point. Living; South Australia.
S. maculata, Busk	1			4†	5†	6		8†	9	10				14‡	15*	16		Bullenmerri,* Fishing Pt., C.O., and living, Australia.
S. marginata, T. Woods	1			4†	5	6		8†	9	10	11	12		14	15	16		Belmont,* Lake Gnotuk. Living, Australia.

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L. mamillifera, Map. - -						6												
L. monilifera, Milne, Ed., sp. -	1					6		8†						14‡		16		
L. mucronata, Smitt - -						6*												Living; North Atlantic.
L. nodulosa, McG. - - -	1				5*	6				10				14‡	15	16		Living; Australia.
L. obliqua, McG. - - -																16*		
L. pachystoma, McG. - -											11*							
L. partipunctata, Map. - -																16		
L. perforata, McG. - - -														14‡	15*	16		
L. pertusa, Esper., sp. - -						6*								14‡				Living; Australia, Europe, North America.
L. praeclara, McG. - - -					5*													
L. quadrata, McG. - - -															15*	16		Living; Australia.
L. quadratipunctata, Map. -						6												
L. radiata, Map. - - -						6				10						16		
L. rectilineata, Hincks - -											11*							Living; New Zealand.
L. rotundata, McG. - - -																		Lake Bullenmerri.*
L. spatulata, Waters - -						6		8†							15*			
L. subimmersa, McG. - -											11*					16		Living; Australia.
L. vagans, McG. - - -																16*		
L. vallata, McG. - - -											11*			14‡				
L. vermicularis, McG. - -	1				5					10						16		

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Gen. *Steganoporella*, Smitt.																		
S. depressa, McG. - - -											11*			14‡				
S. lateralis, McG. - - -						6*								14‡		16		Living; Tahiti & Torres Straits.
S. magnilabris, Busk - -			3	4	5	6				10	11*	12	13	14	15	16		Living; Australia, New Zealand, Japan, etc.
Fam. MICROPORIDAE.																		
Gen. *Micropora*, Gray.																		
M. carinata, Map. - - -																16		
M. elegans, Map. - - -	1																	
M. lunipunctata, Map. - -	1																	
M. ordinata, Waters - -				4†														
M. perforata, McG. - -		2														16†		Living; Australia.
Gen *Macropora*, McG.																		
M. centralis, McG. - - -						6*								14‡			17	
M. clarkei, T. Woods, sp. -			3	4	5	6					11*						17	Fishing Point, C.O.
M. cribrilifera, Map. - -																16		
Fam. CRIBRILINIDAE.																		
Gen. *Membraniporella*, Smitt.																		
M. decorata, Map. - - -															15			

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M. distans, McG. - - -						6*												Living; Victoria.
M. nitida, Johnst. - -				4†														Living; European seas.
M. rugosa, Map. - - -																16		
M. tenuicosta, McG. - -						6								14‡	15*			
Gen. *Cribrilina*, Gray.																		
C. cornuta, McG. - - -					5	6	7*		9		11		13*	14	15	16		
C. dentipora, Waters - -						6		8†			11			14‡	15	16	17	
C. elevata, McG. - - -						6			9	10	11			14‡	15*	16		North Shore, Geelong.
C. orbicula, McG. - - -						6				10				14‡				
C. radiata, Moll., sp. - -	1	2				6								14‡	15*	16		Living; Cosmopolitan.
C. suggerens, Waters - -						6		8†							15	16*		
C. terminata, Waters - -			3	4*	5	6		8†		10	11	12	13	14‡	15	16	17	Lake Bullenmerri.*
C. tubulifera, Hincks - -						6†												Living; Bass Straits.
C. turgida, Map. - - -	1																	
Gen. *Corbulipora*, McG.																		
C. ampulla, Map. - - -														14‡	15			
C. ornata, McG. - - -	1				5	6								14‡	15	16		

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Fam. HIANTOPORIDAE.																		
Gen. *Hiantopora*, McG.																		
H. halli, McG. - - -						6*								14‡	15			
H. liversidgei, T. Woods, sp. -	1	2				6		8†		10			13*	14‡	15	16	17	
H. magna, McG. - - -						6								14‡		16		
H. monoceros, Busk, sp. - -						6								14‡	15	16		Living ; Victoria.
Fam. MICROPORELLIDAE.																		
Gen. *Microporella*, Hincks.																		
M. ciliata, Linn., sp. - -	1													14‡		16†		Living ; Cosmopolitan.
M. didema, McG. - - -														14‡		16*		Living ; Australia and Zealand.
M. macropora, Stol. - - -																	17	
M. malusii, Aud., sp. - -					5†									14‡	15*	16		Living ; Cosmopolitan.
M. marginata, Map. - -					5													
M. rudis, McG. - - -														14‡	15*			
M. rugosa, Map. - - -						6												
Gen. *Tessaradoma*, Norman.																		
T. elevata, Waters, sp. - -						6		8†		10	11	12		14‡	15*	16		Lake Gnotuk.
T. magnirostris, McG. - -						6*									15*			Living ; Australia.

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Gen. *Adeona*, Lamx.																		
A. cellulosa, McG.						6†								14‡	15*			Living; Australia.
A. clavata, Stol., sp.		2			5	6		8†		10				14	15	16		Living; Australia.
A. grisea, Lamx.						6			9	10	11			14	15	16		Living; Australia.
A. mucronata, McG.					5	6		8†	9	10	11			14	15	16		Murgheboluc, Belmont. Living; Australia.
A. obliqua, McG.					5	6		8†	9	10	11	12	13	14	15	16		Murgheboluc.
A. symmetrica, Waters, sp.		2			5	6		8†	9	10	11			14‡	15	16		Murgheboluc.
Gen. *Dimorphocella*, Map.																		
D. pyriformis, Map.																16		
D. triton, McG., sp.														14‡	15*	16		
Gen. *Escharipora*, Smitt.																		
E. stellata, Smitt		2				6									15	16		Living; Florida and Victoria.
Fam. LEPRALIIDAE. Gen. *Lepralia*, Johnston.																		
L. abdita, McG.															15			
L. airensis, Map.		2																
L. bairnsdalei, Waters																16		

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L. bisinuata, Map. - - -																16		
L. burlingtoniensis, Waters -	1	2	3		5						11				15	16	17	Nhill.
L. calopora, Map. - - -						6								14‡				
L. cava, McG. - - - -																16		Lake Bullenmerri.*
L. clavata, Map. - - -						6												
L. cleidostoma, Smitt - -																		
var. rotunda, Waters -								8†										Living; Bass Straits.
L. continua, McG. - - -						6*					11					16		
L. corrugata, Waters - -						6*		8†			11		13*	14	15	16		Lake Bullenmerri.
L. costata, Map. - - -						6										16		
L. crassatina, Waters, sp. -				4†		6					11*							Living; New Zealand.
L. cribrosa, Map. - - -																		Jimmy's Point.
L. depressa, Busk - - -																16†		Living; N.S.Wales and northern seas.
L. duplex, McG. - - -																16*		
L. elongata, McG. - - -					5	6*					11*			14‡		16	17	
L. filiformis, Waters, sp. -															15*			
L. gippslandii, Waters - -														14‡		16*		
L. graysoni, McG. - - -											11*							
L. hamiltoniensis, McG. - -						6												
L. hebetata, Waters, sp. - -											11*			14‡				

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L. mamillifera, Map.						6												
L. monilifera, Milne, Ed., sp.	1					6		8†						14‡		16		
L. mucronata, Smitt						6*												Living; North Atlantic.
L. nodulosa, McG.	1				5*	6				10				14‡	15	16		Living; Australia.
L. obliqua, McG.																16*		
L. pachystoma, McG.											11*							
L. partipunctata, Map.																16		
L. perforata, McG.														14‡	15*	16		
L. pertusa, Esper., sp.						6*								14‡				Living; Australia, Europe, North America.
L. praeclara, McG.					5*													
L. quadrata, McG.															15*	16		Living; Australia.
L. quadratipunctata, Map.						6												
L. radiata, Map.						6				10						16		
L. rectilineata, Hincks											11*							Living; New Zealand.
L. rotundata, McG.																		Lake Bullenmerri.*
L. spatulata, Waters						6		8†							15*			
L. subimmersa, McG.											11*					16		Living; Australia.
L. vagans, McG.																16*		
L. vallata, McG.											11*			14‡				
L. vermicularis, McG.	1				5					10						16		

Species.	Cape Otway. 1	Aire Coast. 2	Darriman's 3	Waurn Ponds. 4	Spring Creek. 5	Muddy Creek, Lower Beds. 6	Gellibrand. 7	urdie's Creek. 8	Shelford. 9	Fyansford. 10	Griffins. 11	Filter Quarries. 12	Corio Bay. 13	Campbell's Point. 14	Mornington. 15	Mitchell River. 16	Flinders. 17	Other Localities.
Gen. *Bulbipora*, McG.																		
B. areolata, McG. - - -						6								14‡				
Gen. *Plagiopora*, McG.																		
P. disticha, McG. - - -	1				5	6					11			14‡	15	16		Murgheboluc.
Gen. *Ovaticella*, Map.																		
O. turbinata, Map. - - -																16		
Gen. *Trigonopora*, Map.																		
T. vermicularis, Map. - -	1	2																
Fam. SCHIZOPORELLIDAE.																		
Gen. *Schizoporella*, Hincks.																		
S. acuminata, Hincks - -																16†		Living; Bass Straits.
S. alata, McG. - - - -						6	7								15	16	17	
S. ambigua, Map. - - -																16		
S. amphora, Waters - -								8†										
S. arachnoides, McG. - -						6								14‡				Living; Australia.
S. auriculata, Hassall - -					5*	6					11			14‡		16†		Living; European seas.
S, australis, T. Woods - -					5*	6		8†		10	11			14‡	15	16		

Species.	1 Cape Otway.	2 Aire Coast.	3 Darriman's.	4 Waurn Ponds.	5 Spring Creek.	6 Muddy Creek, Lower Beds.	7 Gellibrand.	8 Curdie's Creek.	9 Shelford.	10 Fyansford.	11 Griffins.	12 Filter Quarries.	13 Corio Bay.	14 Campbell's Point.	15 Mornington.	16 Mitchell River.	17 Flinders.	Other Localities.
S. biaperta, Michelin, sp. -						6*												Living; Northern seas, Bass Straits and New Zealand.
S. bombycina, Waters - -																16*		
S. cecilii, Audouin, sp. - -																16		Living; Cosmopolitan.
S. chlithridiata, Map. - -						6												
S. conservata, Waters - -								8†								16		
S. convexa, McG. - - -						6*								14‡		16	17	
S. crenulata, McG. - - -														14‡	15			
S. daedala, McG. - - -	1					6					11*			14‡	15*	16	17	Nhill. Living; Australia.
S. excubans, Waters - -								8†										
S. fenestrata, Waters - -					5	6		8†		10	11		13*		15	16	17	Fishing Point, C.O.
S. flabellata, Map. - - -																16		
S. foveata, McG. - - -																16*		
S. granulata, McG. - - -						6									15*			
S. hispida, Map. - - -						6								14‡				
S. lata, McG. - - - -														14‡		16		Living; Australia.
S. mamillata, Map. - - -																		Jimmy's Point.
S. nitens, McG. - - -						6*									15			
S. nitidissima, Map. - -																16		
S. ovalis, Map. - - -																16		
S. phymotopora, Reuss - -	1	2	3		5	6		8†	9	10	11		13	14‡	15	16	17	Living; North Pacific.

Species.	Cape Otway. 1	Aire Coast. 2	Darriman's. 3	Waurn Ponds. 4	Spring Creek. 5	Muddy Creek, Lower Beds. 6	Gellibrand. 7	Curdie's Creek. 8	Shelford. 9	Fyansford. 10	Griffins. 11	Filter Quarries. 12	Corio Bay. 13	Campbell's Point. 14	Mornington. 15	Mitchell River. 16	Flinders. 17	Other Localities.
S. plagiostoma, McG. - -					5	6				10	11*		13	14‡	15			
S. protensa, Waters - -																16		
S. pulvinata, Map. - - -						6												
S. ridleyi, McG. - - -						6*										16		Living; Patagonia and Australia.
S. rostrata, McG. - - -																16*		Living; Australia.
S. rugosa, McG. - - -															15*			
S. schizostoma, McG. - -				4†										14‡	15*	16*		Living; Australia.
S. spiroporina, Waters - -								8†										
S. strictifissa, McG. - -						6				10						16*		
S. subgranulata, Map. - -	1																	
S. submersa, Waters - -		2			5	6		8†	9	10	11			14	15	16*		Belmont, Murgheboluc.
S. subsinuata, Hincks - -														14‡		16		Living; Australia.
S. terebrata - - - -																16		
S. triangula, Hincks - -														14‡				Living; Bass Straits, South Australia, and N.S.W.
S. variabilis, Map. - - -		2																
S. ventricosa, Hasw. - -								8†								16†		Living; Queensland.
S. vigilans, Waters - - -	1	2						8†										

Gen. *Schizoporellopsis*, Map.

Species.	1 Cape Otway.	2 Aire Coast.	3 Darriman's.	4 Waurn Ponds.	5 Spring Creek.	6 Muddy Creek, Lower Beds.	7 Gellibrand.	8 Curdie's Creek.	9 Shelford.	10 Fyansford.	11 Griffins.	12 Filter Quarries.	13 Corio Bay.	14 Campbell's Point.	15 Mornington.	16 Mitchell River.	17 Flinders.	Other Localities.
Gen. *Haswellia*, Busk.																		
H. longirostris, McG. - -						6*								14‡	15			Living; Australia.
H. producta, McG. - - -	1	2				6				10	11		13	14‡	15*	16	17	
Gen. *Gemellipora*, Smitt.																		
G. auriculata, Map. - -																16		
G. elegantissima, McG. - -						6								14‡				
G. polita, McG. - - -	1																17	
Gen. *Characodoma*, Map.																		
C. halli, Map. - - - -						6				10				14‡	15	16		
Gen. *Bipora*, Whitelegge.																		
B. cancellata, Busk, sp. - -								8†						14‡	15	16*		Living; Phillipine Islands and New Guinea.
B. elegans, D'Orb. - - -																		Jimmy's Point. Living; N.S.W. and China.
B. phillipensis, Busk, sp. -						6								14‡	15	16		Lake Gnotuk. Living; N.S.W.
Gen. Trypocella, Map.																		
T. excavata, Map. - - -					5													

Species.	Cape Otway. 1	Aire Coast. 2	Darriman's 3	Waurn Ponds. 4	Spring Creek. 5	Muddy Creek, Lower Beds. 6	Gellibrand. 7	urdie's Creek. 8	Shelford. 9	Fyansford. 10	Griffins. 11	Filter Quarries. 12	Corio Bay. 13	Campbell's Point. 14	Mornington. 15	Mitchell River. 16	Flinders. 17	Other Localities.
Fam. SMITTIIDAE.																		
Gen. *Porella*, Gray.																		
P. angustata, Map. - - -																16		
P. areolata, Map. - - -					5													
P. concinna, Busk, sp. - -						6					11			14‡	15*	16		Living; Europe, North America and Australia.
P. dennanti, Map. - - -																16		
P. denticulata, Stol. - -								8†								16		
P. flabellaris, McG. - - -											11							
P. innocua, McG. - - -	1										11*			14‡		16*		
P. marsupium, McG. - -				4†		6*												Living; Australia.
P. minutissima, Map. - -																16		
P. otwayensis, Map. - -	1																	
P. punctata, McG. - - -											11*			14‡		16*		
P. rhomboidalis, Map. - -															15			
Gen. *Smittia*, Hincks.																		
S. anceps, McG. - - -								8†								16		Living; Victoria.

Species.	1 Cape Otway.	2 Aire Coast.	3 Darriman's.	4 Waurn Ponds.	5 Spring Creek.	6 Muddy Creek, Lower Beds.	7 Gellibrand.	8 Curdie's Creek.	9 Shelford.	10 Fyansford.	11 Griffins.	12 Filter Quarries.	13 Corio Bay.	14 Campbell's Point.	15 Mornington.	16 Mitchell River.	17 Flinders.	Other Localities.
S. centralis, *var.* laevigata, Waters -								8†								16		
S. collaris, Norm. -				4†														Living ; European seas.
S. cribraria, McG. -					5	6*								14‡				
S. depressa, McG. -						6*										16*		
S. intermedia, McG. -						6*												
S. lateralis, McG. -											11*					16*		
S. macgillivrayi, Map., sp. -			3		5*	6				10	11	12		14‡		16		
S. modesta, McG. -																16		
S. napierii, Waters -				4†														Living ; N.S.Wales.
S. nitida, Verrill -																16†		Living ; North America, Africa and Mediterranean.
S. oculata, McG. -															15*			Living ; Victoria.
S. ordinata, McG. -			3			6*				10	11*			14‡	15*	16	17	
S. porinoides, McG. -					5*													
S. reticulata, J. McG., sp -						6*					11*			14‡	15	16†	17	Nhill. Living; Europe & Australia.
S. reticulata, *var.* nitida, McG.																16		
S. tatei, T. Woods, sp. -	1	2	3		5	6		8†		10	11	12		14‡	15	16	17	
Gen. *Cucullipora*, McG.																		
C. tetrasticha, McG. -	1				5	6			9	10	11			14	15	16		Murgheboluc.

Species.	1 Cape Otway.	2 Aire Coast.	3 Darriman's.	4 Waurn Ponds.	5 Spring Creek.	6 Muddy Creek, Lower Beds.	7 Gellibrand.	8 Curdie's Creek.	9 Shelford.	10 Fyansford.	11 Griffins.	12 Filter Quarries.	13 Corio Bay.	14 Campbell's Point.	15 Mornington.	16 Mitchell River.	17 Flinders.	Other Localities.
Gen. *Pachystomaria*, McG.																		
P. parvipuncta, McG. - -						6*					11			14‡		16		
Gen. *Phylactella*, Hincks.																		
P. cribrosa, Map. - - -		2																
P. porosa, McG. - - -					5						11*				15		17	
Gen. *Mucronella*, Hincks.																		
M. airensis, Map. - - -		2																
M. apiculata, McG. - - -																16*		
M. conica, Map. - - -												12					17	
M. duplicata, Waters - -								8†										
M. elegans, McG. var. - -								8†										
M. irregularis, Map. - -																16		
M. lata, McG. - - -						6	7			10		12	13*	14‡	15*			
M. mooraboolensis, McG. -											11*			14‡				
M. personata, Map. - -	1																	
M. porosa, Hincks - - -								8†										Living; Phillipine Islands.
M. praestans, Hincks - -			3			6	7						13*	14‡	15	16		Living; Australia and New Zealand.
M. proboscoides, Map. - -											11							

Species.	1 Cape Otway.	2 Aire Coast.	3 Darriman's.	4 Waurn Ponds.	5 Spring Creek.	6 Muddy Creek, Lower Beds.	7 Gellibrand.	8 Curdie's Creek.	9 Shelford.	10 Fyansford.	11 Griffins.	12 Filter Quarries.	13 Corio Bay.	14 Campbell's Point.	15 Mornington.	16 Mitchell River.	17 Flinders.	Other Localities.
M. spongiosa, McG. - -										10	11*							
M. teres, Hincks - - -						6*								14‡				Living; Australia.
M. tricuspis, Hincks - -																16		Living; Victoria.
M. vultur, Hincks - - -						6					11*				15	16		Living; Australia.
Gen. *Bracebridgia*, McG.																		
B. geometrica, Reuss, sp. -	1				5	6				10				14		16		Living; Australia.
Gen. *Rhyncopora*, Hincks.																		
R. bispinosa, Johnston, sp. -						6*												Living; Europe and Australia.
R. longirostris, Hincks - -						6*				10								Living; Victoria.
R. spinifera, McG. - - -											11*			14‡				
Gen. *Aspidostoma*, Hincks.																		
A. airensis, Map. - - -		2																
A. crassum, Hincks - -				4														Living; Patagonia and Falkland Island.
Gen. *Porina*, D'Orb.																		
P. clypeata, Waters - -								8†								16		
P. columnata, Waters - -								8†										

Species.	1 Cape Otway.	2 Aire Coast.	3 Darriman's	4 Waurn Ponds.	5 Spring Creek.	6 Muddy Creek, Lower Beds.	7 Gellibrand.	8 urdie's Creek.	9 Shelford.	10 Fyansford.	11 Griffins.	12 Filter Quarries.	13 Corio Bay.	14 Campbell's Point.	15 Mornington.	16 Mitchell River.	17 Flinders.	Other Localities.
P. cribraria, McG. - - -						6	7							14‡	15*	16	17	
P. gracilis, Milne, Ed., sp. -	1	2	3	4	5	6		8†	9	10	11	12	13	14	15	16	17	Belmont.* Living; Australia.
P. larvalis, McG. - - -						6				10	11*		13			16	17	Living; Victoria.
P. tuberculata, Map. - -							7											
Gen. *Palmicellaria*, Alder.																		
P. quadrifrons, Map. - -	1	2																
P. skenei, Ell. and Sol. - -																16†		Living; Northern seas.
P. uniserialis, Map. - -																16		
Fam. TUBUCELLARIIDAE.																		
Gen. *Tubucellaria*, D'Orb.																		
T. cereoides, Ell. and Sol. -			3			6				10	11*			14‡		16		Living; Victoria & Lord Howe's Island.
T. marginata, McG. - -						6				10				14	15*	16	17	
Fam. PROSTOMARIIDAE.																		
Gen. *Prostomaria*, McG.																		

Species.	Cape Otway. 1	Aire Coast. 2	Darriman's. 3	Waurn Ponds. 4	Spring Creek. 5	Muddy Creek, Lower Beds. 6	Gellibrand. 7	Curdie's Creek. 8	Shelford. 9	Fyansford. 10	Griffins. 11	Filter Quarries. 12	Corio Bay. 13	Campbell's Point. 14	Mornington. 15	Mitchell River. 16	Flinders. 17	Other Localities.
Fam. CELLIPORIDAE.																		
Gen. *Lekythopora*, McG.																		
L. hystrix, McG. - -						6*					11*		13*	14‡	15*	16	17	Fishing Point, C.O., North Shore, Geelong. Living; Australia.
L. kitsoni, Map. - - -			3	4										14‡			17	Nhill.
L. mooraboolensis, Map. -											11							
Gen. *Cellepora*, Fabricius.																		
C. abdita, McG. - - -															15*			
C. albirostris, Smith, sp. - -															15*			Living; Australia and Florida.
C. fossa, Haswell, sp. - -	1			4	5	6		8†	9	10	11				15	16		Living; Australia.
C. gambierensis, Busk - -					5											16		Nhill.
C. pumicosa, Busk, non Linn. -																16†		
C. serrata, McG. - - -					5*													
C. stellata, Map. - - -										10				14				
C. tridenticulata, Busk - -						6							13*	14‡	15*	16*		Living; Australia.
„ *var.* nummularia, Busk					5*		7						13*		15*			
C. yarraensis, Waters - -								8†								16†		
Gen. *Schismopora*, McG.																		
S. circumvallata, Map. - -					5													

Species.	Cape Otway. 1	Aire Coast. 2	Darriman's. 3	Waurn Ponds. 4	Spring Creek. 5	Muddy Creek, Lower Beds. 6	Gellibrand. 7	Curdie's Creek. 8	Shelford. 9	Fyansford. 10	Griffins. 11	Filter Quarries. 12	Corio Bay. 13	Campbell's Point. 14	Mornington. 15	Mitchell River. 16	Flinders. 17	Other Localities.
S. costata, McG. - - -						6*					11*		13*			16		Living; Victoria.
S. costazei, Aud., sp. - -											11*			14‡		16*		Living; Australia.
S. granum, Hincks - - -																16		Living; Australia.
S. incus, McG. - - -															15*			
S. modesta, McG. - - -						6*												
S. otwayensis, Map. - -	1																	
Gen. *Lagenipora*, Hincks.																		
L. airensis, Map. - - -		2														16		
L. morningtoniensis, Map. -															15			
Gen. *Aulopocella*, Map.																		
A. tubulifera, Map. - -		2																
Fam. RETEPORIDAE.																		
Gen. *Retepora*, Imperato.																		
R. aciculifera, McG. - -		2								10				14†	15*			

Species.	Cape Otway. 1	Aire Coast. 2	Darriman's. 3	Waurn Ponds. 4	Spring Creek. 5	Muddy Creek, Lower Beds. 6	Gellibrand. 7	Curdie's Creek. 8	Shelford. 9	Fyansford. 10	Griffins. 11	Filter Quarries. 12	Corio Bay. 13	Campbell's Point. 14	Mornington. 15	Mitchell River. 16	Flinders. 17	Other Localities.
R. beaniana, King - - -						6†				10				14‡	15			Living; Europe.
R. complanata, Map. - -																16		
R. corioensis, McG. - -													13	14‡				
R. delicatula, Map. - -		2																
R. deserta, Waters - - -																16†		
R. fissa, McG. - - - -						6*		8†	9	10	11		13*	14	15*	16*		Living; Florida and Australia.
R. formosa, McG. - - -																16*		Living; Victoria.
R. granulata, McG. - -															15*			Living; Australia.
R. impar, McG. - - -																16*		
R. lineata, McG. - - -														14‡	15*			
R. monilifera, McG. - -						6*									15*			Living; Australia.
R. permunita, McG. - -						6*								14‡				
R. porcellana, McG. - -													13*		15*			Living; Victoria.
R. producta, Busk - - -						6*							13*		15*	16*		Living; Australia.
R. rimata, Waters - - -						6*		8†				12	13	14‡	15*	16	17	
R. schnapperensis, McG. -														14‡	15	16*		
R. sinuosa, McG. - - -														14‡	15*			Living; Australia.
R. subimmersa, McG. - -																16*		
R. tessalata, *var.* benemunita, Hincks -										10				14‡	15*			Living; Victoria.
R. uniserialis, Map. - -																16		

ADDENDUM.

Since the tabulated list was set up I have received from Mr. Waters a copy of his report upon the Polyzoa collected during the voyage of the "Belgica" in the Antarctic Circle, from which it appears that the following of our fossil species are living there:—Schizoporella ridleyi, McG.; Smittia reticulata, J. McG.; Smittia (Porella) marsupium, McG.; and Cellaria dennanti, McG. This last species has not been found living anywhere else, and it is included by Mr. Waters in the list of "common" species.

APPENDIX.

Remarks on the Deposits.

By T. S. Hall.

The marine tertiaries of Southern Australia cover a considerable area, and are rich in fossils, though at present probably not more than half of even the known species are described, these being chiefly mollusca. No very full description of the beds as they are displayed at the various localities as a whole has hitherto been published, nor indeed is as yet possible. The most complete is a series of three papers on their correlation, by the late Professor R. Tate and Mr. J. Dennant, in the Transactions of the Royal Society of South Australia. A large series of papers by various authors on the beds and their fossils will be found chiefly in the same publication and in the Proceedings of this Society. The general sequence is fairly well agreed upon, but there are differences of opinion in individual instances, even where the fauna of these is well known. A valuable census of the fossils, by Messrs. J. Dennant and A. E. Kitson, has been published by the Department of Mines of this State, but it may as well be pointed out again that not half of the fauna is as yet named, so that far-reaching conclusions based on a few simple arithmetical calculations as to percentages and distribution are not likely to be of any value at all.

As to the age of the beds in European terms, differences of opinion exist among those who have given attention to the subject. We are able to recognise three faunas. The most recent

of those containing any extinct forms is of but local distribution. Older than this we have two series which are widely spread, and of these the earlier is the richer in fossils. It is to this lowest series that Mr. Maplestone's fossils, as recorded in this list, belong. Whether or not this oldest set of beds belongs to one geological age or two is still unsettled. Professor Tate, in his later years, divided it into an upper and lower, which he called oligocene and eocene. Most other workers are disinclined to regard the differences as being so fundamental, and think that both belong to the same series, whatever may be its age.

As regards the equivalence of this series to European and North American ones, considerable diversity of opinion exists. The late Professor Tate held, as has just been stated, that the great proportion of the beds was eocene; McCoy, that they were oligocene in the main, and in part miocene. Mr. Pritchard and myself, to escape the confusion thus caused, have called them Barwonian, from the River Barwon, in the basin of which types of most of the deposits occur. Personally, I doubt if correlation with European standards is possible. As regards the localities given by Mr. Maplestone, all are agreed that the beds about Cape Otway and the Aire coastal sections are the oldest. With these some authorities group those at Darriman's Creek, Waurn Ponds and Spring Creek. The latter is, however, the type of Tate's oligocene, and thus, according to his view, quite distinct from the Otway beds. The remaining localities probably all belong to one series as the community of their molluscan contents is considerable.

Mr. Maplestone's specimens came in the main from parcels of earth supplied to him by various collectors, and I have every confidence in the correctness of their localisation.

It may as well be stated that the beds at Darriman's Creek, Waurn Ponds, the Filter Quarries and Flinders consist of limestone, in which the fossils stand out clearly from one another as a rule, though the rock is compact enough to be used extensively in building. The other deposits are grey or blue marls, sometimes of very tough consistency, while at others containing a varying proportion of sand. Differences in the fauna due to these differences in sediment must, of course, exist.

Mr. Maplestone's list will throw light on questions of correlation between the beds themselves and those at a distance.

Art. VII.—*Catalogue of the Marine Shells of Victoria.*

Part VIII.

By G. B. PRITCHARD and J. H. GATLIFF.

[Read 14th July, 1904.]

In view of having received several additional conchological books and papers from Europe since reading the last part of our Catalogue, there are a few additional references and remarks to some of the species contained therein, which it would be as well to take into consideration at this stage. And we also desire it to be noted that in the same part vii. we have wrongly quoted the date of vol. vi. of the second edition of Lamarck's Anim. S. Vert. by Deshayes, as 1819; the correct date is 1835.

Saxicava australis, Lamarck.

See part vii., p. 100.

1818. Corbula australis, Lamarck. Anim. S. Vert., vol. v., p. 495, No. 1.

Obs.—It might be thought peculiar that no remark has been made on S. arctica, Linnaeus, in dealing with this species, but that form has been purposely omitted by us, owing to the confusion and uncertainty surrounding it. Our own form is extremely variable in its amount of deformity, and until a much more critical comparison of both shells and their contents can be made, we think it advisable to keep them distinct.

Mesodesma erycinaea, Lamarck.

See part vii., p. 110.

1818. Crassatella erycinaea, Lamarck. Anim. S. Vert., vol. v., p. 483, No. 9.

Mesodesma glabrella, Lamarck.

See part vii., p. 111.

1818. Amphidesma glabrella, Lamarck. Anim. S. Vert., vol. v., p. 493, No. 13.

ANAPELLA CUNEATA, Lamarck.

See part vii., p. 112.

1818. Crassatella cuneata, Lamarck. Anim. S. Vert., vol. v., p. 483, No. 8.

1818. Crassatella cycladea, Lamarck. Id., vol. v., p. 483, No. 10.

1864. Mactra (Mulinia) pinguis, Crosse and Fischer. Jour. de Conch., vol. xii., p. 349.

1865. Mactra (Mulinia) pinguis, Crosse and Fischer. Id., vol. xiii., p. 427, pl. 11, f. 2.

1897. Crassatella cycladea, Tate. T.R.S. S.A., vol. xxi., pt. 1, p. 46.

1897. Mulinia pinguis, Tate. Id., p. 46.

Obs.—Mr. Hedley has drawn our attention to our omission to refer to Professor Tate's remarks, in which he states distinctly that his examination of the type specimen of C. cycladea in Paris, enabled him to include this as a synonym of the above. Professor Tate in the same paper also states that he regards Mulinia pinguis, Crosse and Fischer, as a monstrosity of Anapella cuneata forma triquetra.

DONAX DELTOIDES, Lamarck.

See part vii., pp. 118, 119.

1818. Donax deltoides, Lamarck. Anim. S. Vert., vol. v., p. 547, No. 5.

1818. Donax epidermia, Lamarck. Id., p. 548, No. 12.

VENERUPIS EXOTICA, Lamarck.

See part vii., pp. 119, 120.

1818. Venerupis exotica, Lamarck. Anim. S. Vert., vol. v., p. 507, No. 4.

1818. Venerupis carditoides, Lamarck. Id., p. 508, No. 7.

CHORISTODON LUCINALIS, Lamarck.

See part vii., pp. 121, 122.

1818. Petricola lucinalis, Lamarck. Anim. S. Vert., vol. v., p. 504, No. 4.

Obs.—We previously followed several authors in setting this down as Choristodon lapicidum, Chemnitz, but not having access to Chemnitz's work we were unable to see his treatment. As, according to Dr. W. H. Dall (Proceedings of the National Museum of the United States, vol. xxvi., p. 339), a great deal of Chemnitz's work is not binomial, we should apparently accept Lamarck's naming. The type of C. lucinalis, Lamarck, originally came from King George's Sound, New Holland.

CHIONE STRIATISSIMA, Sowerby.

See part vii., pp. 125, 126, to replace Chione cardioides, Lamarck.

Obs.—In our last paper we stated that it was Venus cardioides, Lamarck, from the West Indies which would require a change of name if it proved to be a Chione. Mr. Hedley has drawn our attention to the fact that Deshayes, in his British Museum Catalogue of the Veneridae, did class this species as a Chione, and on referring to the work we find that Deshayes has also correctly included Cytherea cardilla, Lamarck, as a synonym. In dealing with Chione striatissima, Sow., however, we overlooked the fact that Sowerby gave this name for Erycina cardioides, Lamarck, owing to his rather obscure method of doing it without any comment or explanation.

CIRCE PYTHINOIDES, T. Woods.

See part vii., pp. 131, 132.

Obs.—This shell, as already indicated in the previous part of this catalogue, is in the National Museum Collection, Melbourne, and is labelled as from Port Phillip Heads. We have not hitherto seen any other specimens in any Victorian collection, and a re-examination of the type specimens of the above has convinced us that it is synonymous with Circe gibbia, Lamarck (Cytherea), from Queensland and the Pacific. We therefore think that it is highly probable that some mistake may have been originally made in attributing this species to Victorian waters. The type is only a partially grown shell, and therefore not so tumid or elongate as the full grown C. gibbia, but agrees well in all other respects.

CARDIUM TENUICOSTATUM, Lamarck.

See part vii., pp. 136, 137.

1819. Cardium tenuicostatum, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 5, No. 5.

CHAMOSTREA ALBIDA, Lamarck.

See part vii., pp. 137, 138.

1819. Chama albida, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 96, No. 14.

In addition to the above remarks, the present paper includes the remainder of the bivalves, and refers to eighty species contained in the following families:—Ungulinidae, Erycinidae, Leptonidae, Solemyidae, Crassatellitidae, Condylocardiidae, Carditidae, Trigoniidae, Nuculidae, Arcidae, Mytilidae, Philobryidae, Pteriidae, Pinnidae, Spondylidae, Limidae, Anomiidae, Pectenidae, and Ostreidae.

The previous parts of this Catalogue have appeared as follows:—

Part	I.,	published	May,	1898,	containing	85	species.
,,	II.,	,,	February,	1899,	,,	59	,,
,,	III.,	,,	April,	1900,	,,	78	,,
,,	IV.,	,,	August,	1900,	,,	65	,,
,,	V.,	,,	April,	1902,	,,	132	,,
,,	VI.,	,,	February,	1903,	,,	112	,,
,,	VII.,	,,	September,	1903,	,,	96	,,

The total number of species dealt with now amount to 707, which may be summarised as—

Cephalopoda	12
Pteropoda	12
Gastropoda	505
Scaphopoda	2
Lamellibranchiata...	176
Total	707 species

Adding on to this the 41 species of Gastropoda recorded by one of us in the Victorian Naturalist (vol. xx., No. 7, Nov., 1903), which have been discovered subsequent to the publication

of the various parts on the Gastropoda, our Victorian list of Marine Shells now contains 748 species.

We intend to publish a concluding part to this Catalogue which will deal with matters which we regard as requiring revision, together with the additional material since obtained. It will also include a revised Bibliography and Index to facilitate reference.

Family UNGULINIDAE.

Genus **Diplodonta**, Brown, 1831.

DIPLODONTA SPHAERICULA, Angas.

Diplodonta sphaericula, Deshayes, M.S.

1867. Mysia sphaericula, Angas. P.Z.S. Lond., p. 927. No. 92.

1890. Mysia sphaericula, Whitelegge. P.R.S. N.S.W., vol. xxiii., p. 79 in list, No. 133.

Hab.—Western Port.

DIPLODONTA GLOBULARIS, Lamarck.

1818. Lucina globularis, Lamarck. Anim. S. Vert., vol. v., p. 544, No. 20.

1835. Lucina globularis, Lamarck. Id., ed. Desh., vol. vi., p. 231, No. 20.

1839. Lucina globularis, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. ii., p. 577, No. 20.

1842. Lucina globularis, Hanley. Cat. Rec. Biv. Shells, p. 77.

1850. Lucina globularis, Reeve. Conch. Icon., vol. vi., pl. 9, f. 53.

1856. Lucina globularis, Hanley, Cat. Rec. Biv. Shells, p. 348, pl. 14, f. 16.

1887. Diplodonta globularis, Tate. T.R.S. S.A., vol. ix., p. 97, No. 97.

1901. Diplodonta globularis, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 432.

Hab.—Port Phillip; Western Port.

DIPLODONTA ADAMSI, Angas.

1867. Mysia (Felania) adamsi, Angas. P.Z.S. Lond., p. 910, pl. 44, f. 9.

1867. Mysia (Felania) adamsi, Angas. Id., p. 927, No. 94.

1888. Sacchia adamsi, Tate. T.R.S. S.A., vol. x., p. 68, No. 98a.

1893. Diplodonta adamsi, Adcock Hand List Aquatic Moll. S.A., p. 12, No. 119.

Hab.—Port Phillip; Western Port.

Family ERYCINIDAE.

Genus **Kellia**, Turton, 1822.

KELLIA ROTUNDA, Deshayes.

1855. Erycina rotunda, Deshayes. P.Z.S. Lond., p. 181.

1867. Kellia rotunda, Angas. Id., p. 927, No. 98.

1885. Kellia rotunda, var., E. A. Smith. Chall., zool., vol. xiii., p. 202, pl. 11, f. 5-5b.

1887. Kellia rotunda, Tate. T.R.S. S.A., vol. ix., p. 98, No. 101.

1901. Kellya rotunda, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 432.

Hab.—Western Port; off East Moncoeur Island, Bass Straits (Challenger).

KELLIA ROSTELLATA, Tate.

1889. Kellia rostellata, Tate. T.R.S. S.A., vol. xi., p. 63, pl. 11, f. 14.

1901. Kellya rostellata, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 432.

Hab.—Portland, Torquay, Barwon Heads, Flinders, Western Port. Type locality.—"Dredged in life, seven to nine fathoms, attached to seaweed, Port Phillip Heads, Victoria (J. B. Wilson)."

Obs.—Professor Tate does not say where the type specimen of this species is located, but we presume that it was in his

own collection, which has since passed into the possession of Dr. J. C. Verco, of Adelaide.

KELLIA CYCLADIFORMIS, Deshayes.

?1839 Kellia cycladiformis, Deshayes. Trait, Elem. de Conch., pl. 11, f. 6-9.

Hab.—Flinders (Mrs. Kenyon).

Genus **Montacuta**, Turton, 1819.

MONTACUTA SEMIRADIATA, Tate.

1889. Montacuta semiradiata, Tate. T.R.S. S.A., vol. xi., p. 63, pl. 11, f. 2.

Hab.—" Parasitic on Echinocardium, east of Mud Island, Port Phillip, in seven to ten fathoms (J. B. Wilson)." Port Fairy, Flinders, Western Port.

Obs.—The remarks already made on Kellia rosetellata, Tate, also apply to this species.

Genus **Lasaea**, Leach, 1827.

LASAEA RUBRA, Montagu.

1803. Cardium rubrum, Montagu. Test. Brit., p. 83, pl. 83, pl. 27, f. 4.

1853. Kellia rubra, Forbes and Hanley. Brit. Moll., vol. ii., p. 94, pl. 36, f. 5-7, and pl. 0, f. 3.

1863. Lasaea rubra, Jeffreys. Brit. Conch., vol. ii., p. 219, pl. 5, f. 2.

1875. Kellia (Poronia) rubra, Woodward. Man. Moll., p. 459, pl. 19, f. 12.

1884. Lasaea rubra, Tryon. Struct. and Syst. Conch., vol. iii., p. 219, pl. 120, f. 90.

1887. Lasaea rubra, Tate. T.R.S. S.A., vol. ix., p. 99, No. 109.

1901. Lasaea rubra, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 432.

Hab.—Common in rock crevices along the coast generally. Especially associated with Mytilus rostratus.

Obs.—The synonymy of this species being particularly heavy, we have restricted the references to the above works; most of

which are readily accessible to local workers. The following specific names attached to various genera by different authors have been cited as synonyms of this species :—australis, adansonii, fontenayi, nucleola, parreysi, purpurata, scalaris, seminulum, and violacea.

Genus **Mylitta,** D'Orbigny and Recluz, 1850.

MYLITTA TASMANICA, T. Woods.

1875. Pythina tasmanica, T. Woods. P.R.S. Tas., p. 162.
1887. Pythina tasmanica, Tate. T.R.S. S.A., vol. ix., p. 98, pl. 5, f. 12.
1892. Mylitta tasmanica, Tate. Id., vol. xv., p. 135.
1901. Mylitta tasmanica, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3., p. 433.

Hab.—Sandringham, Sorrento, Port Phillip; Shoreham, San Remo, Western Port.

MYLITTA AURICULATA, E. A. Smith.

1891. Mylitta auriculata, E. A. Smith. A.M.N.H., p. 236, pl. 13, f. A to C.
1901. Mylitta auriculata, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 433.

Hab.— Flinders, Western Port.

MYLITTA DESHAYESI, D'Orbigny and Recluz.

1850. Mylitta deshayesi, D'Orbigny and Recluz. Jour. de. Conch., p. 292, pl. 11, f. 12-14.
1887. Pythina deshayesiana, Tate non Hinds. T.R.S. S.A., vol. ix., p. 98, No. 103.

Hab.—Warrnambool; Sorrento.

Family LEPTONIDAE.

Genus **Lepton,** Turton, 1822.

LEPTON TRIGONALE, Tate.

1879. Lepton trigonale, Tate. T.R.S. S.A., vol. ii., p. 131, pl. 5, f. 5.
1887. Lepton trigonale, Tate. Id., vol. ix., p. 99, No. 107.

Hab.—Dredged in Western Port.

LEPTON AUSTRALE, Angas.

1878. Lepton australe, Angas. P.Z.S. Lond., p. 863, pl. 54, f. 14.

1887. Lepton australe, Tate. T.R.S. S.A., vol. ix., p. 98, No. 106.

Hab.—Sorrento, Port Phillip.

Genus **Rochefortia**, Velain, 1876.

ROCHEFORTIA DONACIFORMIS, Angas.

1878. Mysella donaciformis, Angas. P.Z.S. Lond., p. 863, pl. 54, f. 13.

1887. Mysella donaciformis, Tate. T.R.S. S.A., vol. ix., p. 99, No. 110.

1900. Rochefortia donaciformis, Dall. Trans. Wag. Inst., vol. iii., pt. 5, p. 1157.

1901. Rochefortia donaciformis, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 433.

1902. Rochefortia donaciformis, Hedley. P.L.S. N.S.W., vol. xxvii. pt. 1, p. 7, pl. 1, f. 10-14.

Hab.—Hobson's Bay, Sandringham, Sorrento, Port Phillip; Western Port; Torquay.

Genus **Cyamium**, Philippi, 1845.

CYAMIUM MACTROIDES, Tate and May.

1900. Cyamium mactroides, Tate and May. T.R.S. S.A., vol. xxiv., p. 102.

1900. Cyamium mactroides. Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 433, pl. 27, f. 103.

Hab.—Dredged off Rhyll, Western Port.

Family SOLEMYIDAE.

Genus **Solemya**, Lamarck, 1818.

SOLEMYA AUSTRALIS, Lamarck.

1818. Solemya australis, Lamarck. Anim. S. Vert., vol. v., p. 489, No. 1.

1835. Solemya australis, Lamarck. Id., 2nd ed. Desh., vol. vi., p. 124, No. 1.
1839. Solemya australis, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. ii., p. 543, No. 1.
1842. Solemya australis, Hanley. Cat. Rec. Biv. Shells, p. 41.
1856. Solemya australis, Hanley. Id., p. 341, pl. 11, f. 25 (erroneously f. 27 on explanation to plate).
1865. Solemya australis, Angas. P.Z.S. Lond., p. 652, No. 61.
1875. Solemya australis, Reeve. Conch. Icon., vol. xx., pl. 1, f. 5.
1884. Solemya australis, Tryon, Struct. and Syst. Conch., vol. iii., p. 223, pl. 123, f. 63.
1887. Solemya australis, Tate. T.R.S. S.A., vol. ix., p. 99, No. 112.

Hab.—Shoreham, Western Port; Anderson's Inlet (W. H. Ferguson), Otway Coast.

Family CRASSATELLITIDAE.

Genus **Crassatellites**, Kruger, 1823.

CRASSATELLITES AURORA, Adams and Angas.

1863. Crassatella aurora, A. Adams and Angas. P.Z.S. Lond., p. 426, pl. 37, f. 15.
1885. Crassatella aurora, E. A. Smith. Chall. Zool., vol. xiii., Lam., p. 219.
1901. Crassatella aurora, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 433.

Hab.—Off East Moncoeur Island, Bass Straits, 38 fathoms sand and shells (Challenger).

Obs.—Mr. E. A. Smith records the fact that the type of this species was presented to the British Museum by G. F. Angas, and was collected at Bank's Strait, Tasmania. Mr. Hedley (Mem. Aust. Mus., vol. iv., pt. 5, p. 313), in a footnote, suggests that C. carnea, Tate, is probably a synonym of the above species, which he regards as "unrecognised by local workers"; but judging by the treatment of C. aurora by Messrs. Tate and May, the former apparently did not hold this opinion.

Family CARDITIDAE.

Genus **Cardita**, Bruguière. 1789.

CARDITA AMABILIS, Deshayes.

1852. Cardita amabilis, Deshayes. P.Z.S. Lond., p. 102, pl. 17, f. 8, 9.
1878. Cardita amabilis, T. Woods. P.R.S. Tas., p. 54.
1880. Cardita amabilis, Hutton. Man. N.Z., Moll., p. 159.
1901. Cardita amabilis, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 434.

Hab.—Western Port.

CARDITA BIMACULATA, Deshayes.

1852. Cardita bimaculata, Deshayes. P.Z.S. Lond., p. 102, pl. 17, f. 4, 5.
1852. Cardita gunni, Deshayes. Id., p. 101.
1876. Cardita atkinsoni, T. Woods. P.R.S. Tas., p. 27, No. 1.
1878. Cardita gunni, T. Woods. Id., p. 54.
1880. Cardita bimaculata, Hutton. Man. N.Z., Moll., p. 159.
1886. Cardita bimaculata, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, p. 211.
1893. Cardita bimaculata, Adcock. Hand List Aquat. Moll. S.A., p. 13, No. 143.
1901. Cardita bimaculata, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 434.

Hab.—Common in Port Phillip and Western Port.

CARDITA QUOYI, Deshayes.

1852. Cardita quoyi, Deshayes. P.Z.S. Lond., p. 103.
1887. Cardita rosulenta, Tate. T.R.S. S.A., vol. ix., p. 69, pl. 5, f. 3, and p. 100, No. 114.
1901. Cardita quoyi, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 434.

Hab.—Flinders, Western Port.

CARDITA DILECTA, E. A. Smith.

1885. Cardita dilecta, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, 213, pl. 15, f. 4, 4a.

Hab.—Off East Moncoeur Island, Bass Straits, 38 to 40 fathoms (Challenger); Ocean Beach, Point Nepean.

CARDITA BEDDOMEI, E. A. Smith.

1885. Cardita beddomei, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, p. 211, pl. 15, f. 5, 5a.

Hab.—Off East Moncoeur Island, Bass Straits, in 38 to 40 fathoms (Challenger).

Genus **Mytilicardia**, Blainville, 1821.

MYTILICARDIA CRASSICOSTA, Lamarck.

1819. Cardita crassicosta, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 24, No. 13.

1835. Cardita crassicosta, Lamarck. Id. (2nd ed. Desh.), vol. vi., p. 430, No. 13.

1835. Cardita citrina, Lamarck. Id., p. 434, No. 21.

1839. Cardita crassicosta, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. ii., p. 636, No. 13.

1839. Cardita citrina, Lamarck. Id., p. 637, No. 21.

1842. Cardita crassicosta, Hanley. Cat. Rec. Biv. Shells, p. 146.

1843. Cardita crassicostata, Reeve. Conch. Icon., vol. i., pl. 2, f. 7, a, b, c, d, e.

1843. Cardita tridacnoides, Menke. Moll. Nov. Holl., p. 39, No. 222.

1856. Cardita crassicosta, Hanley. Cat. Rec. Biv. Shells, p. 367, pl. 18, f. 19.

1865. Mytilicardia crassicostata, Angas. P.Z.S. Lond., p. 652, No. 63.

1887. Mytilicardia crassicosta, Tate. T.R.S. S.A., vol. ix., p. 100, No. 116.

Hab.—Ocean Beach, Sorrento.

Obs.—Messrs. G. P. Deshayes and Milne Edwards note that Cardita citrina, Lamarck, is represented in the Paris Museum only by a single example; it is a young shell, and is regarded by them as a colour variety of Cardita crassicosta.

MYTILICARDIA CALYCULATA, Linnaeus.

1767. Chama calyculata, Linnaeus. Syst. Nat., p. 1138.
1819. Cardita calyculata, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 24.
1819. Cardita aviculina, Lamarck. Id., p. 26, No. 20.
1835. Cardita calyculata, Lamarck. Id. (2nd ed. Desh.), vol. vi., p. 431, No. 15.
1835. Cardita aviculina, Lamarck. Id., p. 434, No. 20.
1839. Cardita calyculata, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. ii., p. 636, No. 15.
1839. Cardita aviculina, Lamarck. Id., p. 637, No. 20.
1841. Cardita aviculina, Delessert. Recueil de Coq., pl. 11, f. 10 a, b, c.
1842. Cardita calyculata, Hanley. Cat. Rec. Biv. Shells, p. 147.
1842. Cardita aviculina, Hanley. Id., p. 148.
1843. Cardita calyculata, Reeve. Conch. Icon., vol. i., pl. 1, f. 1.
1852. Cardita excavata, Deshayes. P.Z.S. Lond., p. 100, pl. 17, f. 1-3.
1856. Cardita calyculata, Hanley. Cat. Rec. Biv. Shells, p. 367, pl. 18, f. 7.
1856. Cardita aviculina, Hanley. Id., p. 367, pl. 18, f. 24.
1876. Mytilicardia tasmanica, T. Woods. P.R.S. Tas., p. 161.
1885. Cardita calyculata, E. A. Smith. Chall. Zool,, vol. xiii., pp. 14, 210.
1901. Mytilicardia aviculina, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, pp. 434, 462.

Hab.—Port Phillip; Western Port; Back Beach, Sorrento to Flinders; Barwon Heads; Torquay; Station 162, off East Moncoeur Island, Bass Strait, in 38 to 40 fathoms (Challenger).

Obs.—This species has been a somewhat difficult one to deal with, as the original of Linnaeus included two species, hence some of the earlier illustrations are unsatisfactory for the identification of our form. Mr. E. A. Smith in his treatment of C. calyculata includes C. muricata, Reeve, as a synonym, but the latter we take to represent a good Queensland and Pacific species.

Genus **Carditella**, Smith.

CARDITELLA ANGASI, E. A. Smith.

1885. Carditella angasi, E. A. Smith. Chall. Zool., vol. xiii., p. 217, pl. 15, f. 9-9a.

1902. Carditella angasi, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 319.

Hab.—Port Phillip Heads.

Family TRIGONIDAE.

Genus **Trigonia**, Bruguière, 1789.

TRIGONIA MARGARITACEA, Lamarck.

1804. Trigonia margaritacea, Lamarck. Ann. du Mus., vol. iv., p. 355, pl. 67, f. 2.

1819. Trigonia pectinata, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 63, No. 1.

? 1822. Trigonia margaritacea, Sowerby. Genera, pl. 84, f. 1, 2.

1827. Trigonia pectinata, Crouch. Introd. to Lamarck's Conchology, p. 21, pl. 10, f. 10.

1828. Chama pectinata, Wood. Index. Test. Sup., p. 6, pl. 2, f. 6.

1835. Trigonia pectinata, Lamarck. Anim. S. Vert. (2nd ed. Deshayes), vol. vi., p. 514, No. 1.

1835. Trigonia pectinata, Quoy and Gaimard. Astrolabe Zool., vol. iii., p. 474, pl. 78, f. 1-4.

1839. Trigonia pectinata, Lamarck. Anim. S. Vert. (3rd ed. Deshayes and Edwards), vol. ii., 662, No. 1.

1843. Trigonia pectinata, Hanley. Cat. Rec. Biv. Shells, p. 172.

1849. Trigonia margaritacea, Huxley. P.Z.S. Lond., p. 31, pl. 3, f. 1-3.

1850. Trigonia margaritacea, Huxley. A.M.N.H., vol. v., p. 141.

1858. Trigonia margaritacea, H. and A. Adams. Genera, pl. 124, f. 1-1b.

1860. Trigonia margaritacea, Reeve. Conch. Icon., vol. xii., pl. 1, f. 3a-3d.

1875. Trigonia pectinata, Woodward. Man. Moll., pp. 25 and 430, figs. 18 and 221.

1878. Trigonia margaritacea, Angas. P.Z.S. Lond., p. 871.

1884. Trigonia dubia, Sowerby. Thes. Conch., vol. v., p. 188, pl. 492, f. 5.

1885. Trigonia margaritacea, E. A. Smith. Chall. Zool., vol. xiii., p. 224.

1887. Trigonia margaritacea, Tate. T.R.S. S.A., vol. ix., p. 101, No. 124.

1901. Trigonia margaritacea, Hall. P.R.S., n.s., vol. xiv., pt. 1, p. 17, figure in text.

1902. Trigonia margaritacea, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, pp. 301, 302.

Hab.—Western Port, dredged from 5 to 7 fathoms off Rhyll; Port Phillip, off Portsea; off East Moncoeur Island, Bass Strait, 38 fathoms sand and shells (Challenger).

Obs.—A slight variation of this species has been erroneously identified by the late Sir F. McCoy as identical with his fossil species T. acuticostata, originally referred to as from the Older Pliocene Beds of Mordialloc. Fortunately, the living specimens upon which McCoy's determinations were made, have been preserved in the National Museum, and a close comparison has been made between them and the living T. margaritacea on the one hand, and the Miocene or Kalimnan fossil originally described under the name of T. acuticostata on the other, and there can be no doubt whatever, that a misidentification has been made by McCoy as to the recent species, while the fossil form is quite a distinct species. McCoy's name of T.

acuticostata must therefore be still retained for the fossil shell, and we cannot accept Mr. Hedley's treatment in regarding it as a mere variant of T. margaritacea.

Family NUCULIDAE.

Genus Nucula, Lamarck, 1799.

NUCULA MICANS, Angas.

1878. Nucula micans, Angas. P.Z.S. Lond., p. 864, pl. 54, f. 16.

1887. Nucula micans, Tate. T.R.S. S.A., vol. ix., p. 102, No. 125.

1901. Nucula antipodum, Tate and May (non Hanley). P.L.S. N.S.W., vol. xxvi., pt. 3, p. 435.

Hab.—Dredged off Rhyll, Western Port. Corio Bay, Port Phillip.

Obs.—The late Professor Tate identified the above species as N. antipodum, Hanley, for one of us, but on going into the original description of that species, and the particulars and figure given by Sowerby in his Thesaureus Conchyliorum, we consider it to be a distinct species. On the other hand, our shell agrees well with the description and figure given by Angas of N. micans.

NUCULA HEDLEYI, nom. mut.

1877. Nucula minuta, T. Woods (non Gould and others). P.R.S. Tas., p. 156.

1902. Pronucula minuta, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 291, f. 40.

Hab.—Western Port.

Obs.—We agree with Mr. Hedley in his conclusions as to the distinctness of this species from N. antipodum and N. micans, but have been unable to regard it as validly placed in his new genus Pronucula, our examples being apparently indistinguishable from Nucula. In view of the prior use of this specific name by several authors, we have deemed it necessary to change the name as above.

NUCULA OBLIQUA, Lamarck.

1819. Nucula obliqua, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 59, No. 5.

1835. Nucula obliqua, Lamarck. Id. (2nd ed. Desh.), vol. vi., p. 505, No. 5.

1839. Nucula obliqua, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. ii., p. 659, No. 5.

1862. Nucula obliqua, Chenu. Man. de Conch., vol. ii., p. 179, f. 897.

1876. Nucula tumida, T. Woods (non Hinds, Philippi, etc.). P.R.S. Tas., p. iii.

1877. Nucula grayi, T. Woods (non D. Orbigny). Id. p. 55.

1884. Nucula obliqua, Tryon. Struct. and Syst. Conch., vol. iii., p. 248, pl. 126, f. 27.

1886. Nucula tumida, Tate. T.R.S. S.A., vol. viii., p. 127, pl. 6, f. 6a, 6b.

1896. Nucula tenisoni, Pritchard. P.R.S. Vic., vol. viii., n.s. pp. 128-130.

1902. Nucula obliqua, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 292.

Hab.—Dredged alive off Brighton and off Beaumaris, Port Phillip, from sandy mud. St. Kilda, Hobson's Bay.

Obs.—This species, though not very common living on our shores at the present time, was very abundant during Tertiary time, being a very common fossil species in the Victorian Miocene (or Kalimnan) beds, and also extending into the Eocene (or Balcombian) beds, but not in such great abundance. The antiquity of this species is of interest, and its persistency of form is remarkable, while its distribution as a fossil mainly accounts for its synonymy.

Genus Leda, Schumacher, 1817.

LEDA CRASSA, Hinds.

1843. Nucula crassa, Hinds. P.Z.S. Lond., p. 99.

1847. Leda chuva, Gray in Juke's Voy. Fly., vol. ii. app. p. 356, pl. 2, f. 6.

1860. Leda chuva, Sowerby. Thes. Conch., vol. iii., p. 119, pl. 228, f. 67.

1860. Leda crassa, Sowerby. Id., p. 120, pl. 228, f. 69.

1871. Leda crassa, Sowerby in Reeve. Conch. Icon., vol. xviii., pl. 5, f. 27.

1871. Laeda chuva, Sowerby in Reeve. Id., pl. 7, f. 46.

1877. Leda crassa, Angas. P.Z.S. Lond., p. 193.

1878. Leda crassa, T. Woods. P.R.S. Tas., p. 32.

1885. Leda crassa, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, p. 237.

1887. Leda crassa, Tate. T.R.S. S.A., vol. ix., p. 102, No. 126.

1902. Leda crassa, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 294.

Hab.—Western Port; Anderson's Inlet (W. H. Ferguson); Port Albert (T. Worcester); off entrance to Port Phillip 38 fathoms (Challenger). Apollo Bay.

Obs.—This species is also a common Miocene or Kalimnan fossil in Gippsland, and also occurs in the Pliocene or Werrikooian Beds at Limestone Creek, Western Victoria.

LEDA ENSICULA, Angas.

1877. Leda ensicula, Angas. P.Z.S. Lond., p. 177, pl. 26, f. 27.

1885. Leda ensicula, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, p. 239.

1902. Leda ensicula, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 293, f. 41.

Hab.—Off the entrance to Port Phillip, in 33 fathoms sand, (Challenger).

Obs.—Type in the British Museum dredged off Port Jackson Heads in 45 fathoms. We agree with Mr. Hedley in regarding L. lefroyi, Beddome, as a distinct species from the above, the type of the latter being in the Hobart Museum, and has been examined by one of us.

Family Arcidae.

Genus **Arca**, Linnaeus.

Arca navicularis, Bruguière.

1797. Arca navicularis, Bruguière. Encyc. Meth. vers., p. 99.
1817. Arca navicularis, Dillwyn. Desc. Cat. Rec. Shells, p. 227.
1825. Arca navicularis, Wood. Index. Test., p. 44, pl. 9, f. 5.
1843. Arca navicularis, Hanley. Cat. Rec. Biv. Shells, p. 152.
1844. Arca navicularis, Reeve. Conch. Icon., vol. ii., pl. 11, f. 70.
1887. Arca navicularis, Tate. T.R.S. S.A., vol. ix., p. 102, No. 127.

Hab.—Victoria (E. A. Smith teste Prof. R. Tate).

Obs.—We have not yet found this species on our shores.

Genus **Barbatia**, Gray, 1840.

Barbatia fasciata, Reeve.

1844. Arca fasciata, Reeve. P.Z.S. Lond., p. 125.
1844. Arca fasciata, Reeve. Conch. Icon., vol. ii., pl. 15, f. 99.
1860. Anomalocardia carpenteri, Dunker. Nov. Conch., pl. 30, f. 7-9.
1867. Barbatia fasciata, Angas. P.Z.S. Lond., p. 931.
1878. Arca fasciata, T. Woods. P.R.S. Tas., p. 55.
1885. Arca (Barbatia), fasciata, E. A. Smith. Chall. Zool. Lamelli, vol xiii., p. 260.
1885. Arca (Barbatia) radula, E. A. Smith. Id., p. 260, pl. 17, f. 3-3b.
1892. Barbatia carpenteri, Tate. T.R.S. S.A., vol. xv., pt. 2, p. 136.
1897. Barbatia carpenteri, Tate. T.R.S. S.A., vol. xxi., pt. 1, p. 48.

1901. Barbatia carpenteri, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 436.

Hab.—Common in Port Phillip and generally distributed along the coast.

Obs.—It is evident that Messrs. Tate and May have become confused over Arca trapezia, Deshayes, and Arca trapezina, Lamarck; the latter is recorded from King Island by its author, and, judging from his description and from Delessert's figure, it is closely allied to Barbatia fasciata, Reeve, but although we have a big series showing much diversity of form and distortion, we cannot match Lamarck's species. Reeve gives a good figure of the normal form of our shell, and we fail to recognise two species as indicated by the Challenger Report. The type of A. fasciata, Reeve, is given as habitat unknown, and is in the Cuming Collection in the British Museum.

BARBATIA SQUAMOSA, Lamarck.

1819. Arca squamosa, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 45, No. 35.

1828. Arca squamosa, Wood. Index. Test., Sup., p. 7, pl. 2, f. 12.

1835.—Arca squamosa, Lamarck. Anim. S. Vert. (2nd ed. Desh.), vol. vi., p. 474, No. 35.

1839. Arca squamosa, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. ii., p. 649, No. 35.

1843. Arca squamosa, Hanley. Cat. Rec. Biv. Shells, p. 158.

1865. Barbatia (Acar) laminata, Angas. P.Z.S. Lond., p. 655, No. 84.

1878. Arca maccoyi, T. Woods. T.R.S. Vic., vol. xiv., p. 61.

1887. Barbatia laminata, Tate. T.R.S. S.A., vol. ix., p. 103, No. 131.

1897. Barbatia squamosa, Tate. Id., vol. xxi., pt. 1, p. 48.

1901. Barbatia squamosa, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 436.

Hab.—Common under stones in Western Port at low tide; Port Phillip; Otway Coast.

Obs.—This species is very frequently much distorted, and small forms are often relatively very tumid and solid. Messrs. Tate and May in their Tasmanian census unite Arca pusilla, Sowerby, with this species, but we consider it to be distinct. The type specimen of Arca maccoyi, T. Woods, is in the National Museum, Melbourne. The type of Arca squamosa is from King Island, and is in the Museum d'Historie Naturelle, Paris.

BARBATIA TRAPEZIA, Deshayes.

1840. Arca trapezia, Deshayes. Rev. Zool. Soc. Cuv., p. 358.

1840. Arca trapezia, Deshayes. Mag. de-Zool. (Guerin's), Mollusques, plate 21, 3 figures.

1844. Arca lobata, Reeve. Conch. Icon., vol. ii., No. 19, pl. 3, f. 19.

1844. Arca trapezia, Reeve. Id., in index to monograph only.

1856. Arca trapezia, Hanley. Cat. Rec. Biv. Shells, p. 374, pl. 18, f. 40.

1867. Anomalocardia trapezia, Angas. P.Z.S., p. 931, No. 121.

1887. Barbatia trapezia, Tate. T.R.S. S.A., vol. ix., p. 102, No. 130.

1892. Anomolocardia trapezia, R. Etheridge. Geo. and Pal. Queensland, p. 641, pl. 36, f. 10-12.

Hab.—Dredged alive in Western Port; Port Albert.

Obs.—Now apparently extinct in Hobson's Bay, but known living commonly to the early colonists in the neighbourhood of Port Melbourne. It is very abundant in the old estuarine deposits of the West Melbourne Swamp of Pleistocene age extending as far north as Kensington at least, and it is also commonly obtained in the dredgings for the harbour improvements.

The type of Arca lobata, Reeve, is in the National Museum, Melbourne, having been obtained from Reeve many years ago.

Genus **Glycimeris**, Da Costa, 1778, non Klein, Lamarck, etc.

GLYCIMERIS FLABELLATUS, T. Woods.

1878. Pectunculus flabellatus, T. Woods. T.R.S. Vic., vol. xiv. pp. 61, 62.

1878. Pectunculus laticostatus, Angas (non Quoy and Gaimard). P.Z.S. Lond. p. 871.
1897. Pectunculus orbicularis, Angas. Id., p. 420, pl. 35, f. 9.
1885. Pectunculus beddomei, E. A. Smith. Chall. Zool., vol. xviii., p. 255. pl. 18, f. 1,1b.
1887. Pectunculus flabellatus, Tate. T.R.S. S.A., vol. ix., p. 103, No. 134.
1801. Pectunculus gealei, Tate (non Angas). T.R.S.S.A., vol. xiv., pt. 2, p. 268.
1901. Glycymeris gealei, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 436.

Hab.—Off East Moncoeur Island, Bass Strait, in 38 fathoms sand and shells (Challenger). Portland (Maplestone). Victoria (T. Woods).

Obs.—The type of P. flabellatus, T. Woods, is in the National Museum, Melbourne. From the original figure and description of P. gealei, Angas, we fail to fit it on to the above species as has been done by Professor Tate.

GLYCIMERIS RADIANS, Lamarck.

1819. Pectunculus radians, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 54, No. 18.
1835. Pectunculus radians, Lamarck. Id. (2nd ed. Desh.), vol. vi., p. 495, No. 18.
1839. Pectunculus radians, Lamarck. Id. (3rd. ed. Deshayes and Edwards), vol. ii., p. 656, No. 18.
1843. Pectunculus radians, Hanley. Cat. Rec. Biv. Shells, p. 165.
1843. Pectunculus radians, Reeve. Conch. Icon., vol. i., pl. 9, f. 50a, b.
1856. Pectunculus radians, Hanley. Cat. Rec. Biv. Shells, p. 375, pl. 19, f. 25.
1897. Axinaea radians, Tate. T.R.S. S.A., vol. xxi., pt. 1, p. 48.
1901. Glycymeris radians, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 436.

Hab.—Western Port; San Remo; Portsea; Flinders, Balnarring. Port Phillip (Reeve).

Obs.—The trouble surrounding this species has been apparently due to its misidentification in South Australia (T.R.S. S.A., vol. xxi., pt. 1, 1897, p. 48) as the name of radians was there applied to P. striatularis. We believe that Reeve is correct in his determination of Lamarck's P. radians, and that his P. obliquus is really the synonym of P. striatularis, though perhaps a more oblique variety, but this variation is well illustrated by the series of specimens examined by us.

GLYCIMERIS STRIATULARIS, Lamarck.

1819. Pectunculus striatularis, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 52, No. 13.

1835. Pectunculus striatularis, Lamarck. Id. (2nd. ed. Desh.), vol. vi., p. 493, No. 13.

1839. Pectunculus striatularis, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. ii., p. 655, No. 13.

1843. Pectunculus striatularis, Hanley. Cat. Rec. Biv. Shells, p. 164.

1843. Pectunculus striatularis, Reeve. Conch. Icon., vol. i., pl. 6, f. 27.

1843. Pectunculus holosericus, Reeve. P.Z.S. Lond., p. 34.

1843. Pectunculus holosericus, Reeve. Conch. Icon., vol. i., pl. 4, f. 18.

1843. Pectunculus obliquus, Reeve. Id., pl. 6, f. 33.

1867. Axinia holosericus, Angas. P.Z.S. Lond., p. 932.

1880. Pectunculus striatularis, Hutton. Man. N.Z., Moll., p. 163.

1885. Pectunculus holosericus, E. A. Smith. Chall. Zool., vol. xiii., p. 251.

1897. Axinaea striatularis, Tate. T.R.S. S.A., vol. xxi., pt. 1, p. 48.

1901. Glycymeris striatularis, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 437.

Hab.—Port Phillip, Western Port, Shoreham, San Remo.

GLYCIMERIS AUSTRALIS, Quoy and Gaimard.

1835. Pectunculus australis, Quoy and Gaimard. Astrolabe, Zool., vol. iii., p. 469, pl. 77, f. 7-9.

1856. Pectunculus grayanus, Dunker. P.Z.S. Lond., p. 357.
1887. Pectunculus grayanus, Tate. T.R.S. S.A., vol. ix., p. 103, No. 135
1890. Pectunculus grayana, Whitelegge. P.R.S. N.S.W., vol. xxiii., p. 81, No. 168.
1898. Axinaea kenyoniana, Brazier. P.L.S. N.S.W., vol. xxii., p. 781.
1902. Glycymeris australis, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 299.

Hab.—Lakes Entrance, Port Albert.

Obs.—The type of A. kenyoniana is in the collection of Mrs. A. Kenyon, Melbourne, and has been examined by us.

Genus **Limopsis**, Sassi, 1827.

LIMOPSIS TENISONI, T. Woods.

1865. Limopsis belcheri, McCoy (non Adams and Reeve), A.M. N.H. (3rd ser.), vol. xvi., p. 114.
1875. Limopsis belcheri, McCoy (non Adams and Reeve). Prod. Pal. Vic., Dec. ii., p. , pl. 19, f. 8, 9.
1877. Limopsis cancellata, T. Woods (non Reeve). P.R.S. Tas., p. 156.
1878. Limopsis tenisoni, T. Woods. Id., p. 56.
1881. Limopsis belcheri, Bailey (non Adams and Reeve). Southern Science Record, vol. i., October, p. 170.
1885. Limopsis bassi, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, p.p. 14, 256, pl. 18, f. 6-6a.
1887. Limopsis bassii, Tate. T.R.S. S.A., vol. ix., p. 103, No. 136.
1887. Limopsis belcheri, Tate (non Adams and Reeve). Id., p. 104, No. 137.
1901. Limopsis bassi, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 437.
1902. Limopsis tenisoni, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 297.

Hab.—Off East Moncoeur Island, Bass Strait, 38 fathoms sand and shells, (Challenger). Inverloch, Flinders, San Remo, Warrnambool, Portland (Bailey). Airey's Inlet.

Obs.—This species has long wanted a thorough overhaul, and the treatment it has received by Mr. C. Hedley we are in perfect accord with, and consider that most of the difficulties surrounding it are distinctly cleared thereby.

LIMOPSIS RUBRICATA, Tate.

1887. Limopsis rubricata, Tate. T.R.S. S.A., vol. ix., pp. 71, 104, pl. 5, f. 6.

1901. Limopsis rubricata, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 437.

1902.—Limopsis rubricata, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 297.

Hab.—Dredged off Rhyll, Western Port, commonly associated with Polyzoa. Ocean Beach, Point Nepean,

Obs.—We consider that the generic location of this species is somewhat unsatisfactory, but we are unable at present to suggest a more definite position.

Family MYTILIDAE.

Genus **Mytilus**, Linnaeus, 1758.

MYTILUS PLANULATUS, Lamarck.

1819. Mytilus planulatus, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 125, No. 24.

1836. Mytilus planulatus, Lamarck. Id. (2nd ed. Desh.), vol. vii.. p. 46, No. 24.

1839. Mytilus planulatus, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. iii., p. 21, No. 24.

1843. Mytilus planulatus, Hanley. Cat. Rec. Biv. Shells, p. 249.

1876. Mytilus tasmanicus, T. Woods. P.R.S. Tas., p. 161.

1877. Mytilus latus, var, T. Woods. Id., p. 157.

1878. Mytilus latus, T. Woods (non Lamarck). Id., p. 54.

1878. Mytilus tasmanicus, T. Woods. Id., p. 54.

1897. Mytilus planulatus, Tate. T.R.S. S.A., vol. xxi., pt. 1, p. 49.

1901. Mytilus planulatus, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 437.

Hab.—Very common in Port Phillip; Western Port; Portland (Maplestone).

Obs.—This species has hitherto been commonly known here as Mytilus latus, Lamarck, a New Zealand species, but an examination of the type specimen of M. planulatus, Lamarck, by the late Professor Tate, clearly indicates that our species must be known by that name. In Professor Tate's Revision of the South Australian Mollusca (T.R.S. S.A., vol. ix., p. 105), he refers to M. chorus, Molina, but subsequently in his Critical Remarks on Some Australian Mollusca (Id., vol. xxi., pt. 1. p. 49), he states that M. planulatus is the M. chorus, of his revision, but "the subordination of the name of this species to that of M. chorus, Molina," he "has no opinion upon, having accepted Hutton's views thereon." Professor Hutton in Appendix A to his Manual of N.Z. Mollusca, p. 202, Remarks by Dr. V. Martens, quotes him as saying of M. dunkeri, from Auckland, "Probably not *dunkeri*, but, in my opinion, *chorus*, Molina, which comes from Chili." In Mr. H. Suter's List of New Zealand Species in the Transactions of the N.Z. Institute, he omits any reference to either M. dunkeri, or M. chorus.

During the last few years considerable havoc has been worked on this species by the large starfish Asterias calamaria, which has become very common in many parts of Port Phillip.

The type of this species is from King George's Sound, and is in the Museum d'Histoire Naturelle, Paris.

MYTILUS ROSTRATUS, Dunker.

1856. Mytilus rostratus, Dunker. P.Z.S. Lond., p. 358.

1857. Mytilus rostratus, Reeve. Conch, Icon., vol. x., pl. 5, f. 15.

1865. Mytilus (Aulacomya) rostratus, Angas. P.Z.S. Lond., p. 653, No. 67.

1887. Mytilus rostratus, Tate. T.R.S. S.A., vol. ix., p. 104, No. 140.

1889. Mytilus rostratus, Clessin. Conch. Cab. (ed. Kuster), p. 45, No. 22, erroneously quoted as pl. 17, f. 8, whereas it should be pl. 18, f. 7.

1901. Mytilus rostratus, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 437.

Hab.—Gellibrand coast to Torquay and Barwon Heads; San Remo; Kilcunda, and Anderson's Inlet (W. H. Ferguson); Cape Nelson (Nat. Mus.).

Obs.—The type of this species was obtained from Tasmania, and is in the British Museum.

MYTILUS POLYODONTUS, Quoy and Gaimard.

1835. Mytilus polyodontus, Quoy and Gaimard. Astrolabe, Zool., vol. iii., p. 462, pl. 78, f. 15, 16.

1835. Mytilus polyodontus, Lamarck. Anim. S. Vert. (2nd ed. Desh.), vol. vii., p. 49, No. 37.

1839. Mytilius polyodontus, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. iii., p. 22, No. 37.

1857. Mytilus menkeanus, Reeve. Conch. Icon., vol. x., pl. 7, f. 26.

1865. Mytilus (Aulacomya) menkeanus, Angas. P.Z.S. Lond., p. 653, No. 66.

1880. Mytilus polyodontes, Hutton. Man. N.Z., Moll. p. 167.

1887. Mytilus menkeanus, Tate. T.R.S. S.A., vol. ix., p. 105, No. 141.

1889. Mytilus menkeanus, Clessin. Conch. Cab. (ed. Kuster), p. 38, No. 12, pl. 10, f. 3, 4.

1897. Mytilus polydontes, Tate. T.R.S. S.A., vol. xxi., pt. 1, p. 49.

Hab.—San Remo; Polwarth Coast; Portland (Nat. Mus.).

Obs.—Type from New Holland in the Cuming Collection in the British Museum.

MYTILUS HIRSUTUS, Lamarck.

1819. Mytilus hirsutus, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 120, No. 5.

1836. Mytilus hirsutus, Lamarck. Id. (2nd ed. Desh.), vol. vii., p. 38, No. 5.

1839. Mytilus hirsutus, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. iii., p. 19, No. 5.
1843. Mytilus hirsutus, Hanley. Cat. Rec. Biv. Shells, p. 244.
1865. Mytilus (Aulacomya) hirsutus, Angas. P.Z.S. Lond., p. 652, No. 65.
1867. Mytilus (Aulacomya) hirsutus, Angas. Id., p. 928, No. 105.
1878. Mytilus hirsutus, T. Woods. P.R.S. Tas., p. 54.
1882. Mytilus hirsutus, Dunker. Ind. Moll. Japon, p. 222.
1885. Mytilus hirsutus, E. A. Smith. Chall. Zool., vol. xiii., Lam., p. 273.
1887. Mytilus hirsutus, Tate. T.R.S. S.A., vol. ix., p. 104, No. 139.
1889. Mytilus hirsutus, Clessin. Conch. Cab., p. 40, No. 15, pl. 7, f. 6.

Hab.—Polwarth coast; Kilcunda (W. H. Ferguson).

Genus Modiola, Lamarck, 1799.

MODIOLA ATER, Zelebor.

1866. Mytilus ater, Zelebor. Verhand. der Zool.-bot. Gesell, Wien, p. 914.
1868. Mytilus ater, Frauenfeld. Reise, Novara, vol. vi., p. 16, pl. 2, f. 29, 30.
1871. Perna confusa, Angas. P.Z.S. Lond., p. 21, pl. 1, f. 33.
1873. Mytilus ater, Hutton. Cat. Moll. N.Z., p. 78, No 100.
1877. Mytilus crassus, T. Woods. P.R.S. Tas., p. 157, No. 78.
1878. Mytilus crassus, T. Woods. Id., p. 55.
1880. Mytilus ater, Hutton. Man. N.Z., Moll., p. 167 and p. 202.
1887. Mytilus ater, Tate. T.R.S. S.A., vol. ix., p. 105, No. 142.
1889. Mytilus ater, Clessin. Conch. Cab., p. 62, No. 38, pl. 7, f. 5.

1901. Modiola confusa, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 438.

1901. Mytilus ater, Tate and May. Id., p. 452.

1901. Volsella ater, Suter. Trans. N.Z. Inst., vol. xxxiv., p. 223.

Hab.—Coast generally.

Obs.—The smaller dwarfed form of the M. crassa type exceedingly common on the rocks between tide marks at several localities, especially Back Beach, Sorrento, the larger form being obtained inside the various bays and estuaries, the latter form occurring up the Saltwater River as far as Maribyrnong, a distance of about 10 miles. The difference in habitat of these two forms, the one on exposed rocky shores, the other on muddy river banks and estuaries, frequently in clumps, attached to reeds, might be taken as probably indicating two species, but the forms are so variable that it has seemed best to take the whole as one species.

Modiola inconstans, Dunker.

1856. Volsella inconstans, Dunker. P.Z.S. Lond., p. 363.

1887. Modiola semivestita, Tate (non Dunker). T.R.S. S.A., vol. ix., p. 106, pl. 5, f. 16a, b.

1889. Modiola inconstans, Clessin. Conch. Cab., p. 127, No. 55.

1901. Modiola inconstans, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 438.

Hab.—Hobson's Bay, Williamstown, Sandringham, Portarlington, Corio Bay.

Obs.—This species, though fairly consistent in shape, is somewhat variable in colour, from a uniform light brown to a blue-black, and occasionally parti-coloured.

Modiola albicosta, Lamarck.

1819. Modiola albicosta, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 111, No. 3.

1836. Modiola albicosta, Lamarck. Id. (2nd ed. vol. vii., p. 19, No. 3.

1839. Modiola albicosta, Lamarck. Id. (3rd shayes and Edwards), vol.

1841. Modiola albicosta, Delessert. Recueil de Coq., pl. 13, f. 8.
1843. Modiola albicosta, Hanley. Cat. Rec. Biv. Shells, p. 234.
1857. Modiola albicosta, Reeve. Conch. Icon., vol. x., pl. 2, f. 7.
1862. Modiola albicosta, Chenu. Man. de. Conch., vol. ii., p. 154, f. 758.
1878. Modiola albicostata, T. Woods. P.R.S. Tas., p. 55.
1887. Modiola, albicosta, Tate. T.R.S. S.A., vol. ix., p. 105, No. 145.
1889. Modiola albicosta, Clessin. Conch. Cab., p. 96, pl. 28, f. 6, not pl. 5, f. 5.
1902. Modiola albicosta, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 311.

Hab.—Portsea, Port Phillip; Shoreham, Western Port.

MODIOLA AUSTRALIS, Gray.

1827. Modiola australis, Gray. App. to King's Voyage, vol. ii., p. 477.
1843. Modiola australis, Hanley. Cat. Rec. Biv. Shells, p. 235.
1857. Modiola australis, Reeve. Conch. Icon., vol. x., pl. 5. f. 21.
1865. Perna australis, Angas, P.Z.S. Lond., p. 653, No. 70.
1867. Perna australis, Angas. Id., p. 929, No. 109.
1878. Modiola australis, T. Woods. P.R.S. Tas., p. 55.
1887. Modiola australis, Tate. T.R.S. S.A., vol. ix., p. 105, No. 144.
1889. Modiola australis, Clessin. Conch. Cab., p. 99, No. 9, pl. 29, f. 1, 2 misquoted, should be f. 3, 4.
1897. Modiola australis, Tate, Id., vol. xxi., pt. 1, p. 49.
1901. Modiola australis, Tate and May. P.L.S. N.S.W., vol. xxvi., [illegible] 3. p. 438.
[illegible] . Mem. Austr. Mus.,

Hab.—Common Port Phillip and Western Port. Portland (Maplestone), Kilcunda, and Anderson's Inlet (W. H. Ferguson).

Obs.—The hirsute character of this shell readily distinguishes it from our other species of Modiola.

MODIOLA ARBORESCENS, Chemnitz.

1795. Mytilus arborescens, Chemnitz. Conch. Cab., vol. xi., p. 251, pl. 198, f. 2016, 2017.

1819. Modiola picta, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 112, No. 8.

? 1822. Modiola picta, Sowerby. Genera, vol. ii., pl. 99, f. 1.

1825. Mytilus arborescens, Wood. Index. Test., p. 57, pl. 16, f. 13.

1838. Modiola picta, Lamarck. Anim. S. Vert (2nd ed. Desh.), vol. vii., p. 21, N. 8.

1839. Modiola picta, Lamarck. Id. (3rd. ed. Deshayes and Edwards), vol. iii., p. 12, No. 8.

1843. Modiola arborescens, Hanley. Cat. Rec. Biv. Shells, p. 237.

1855. Modiola arborescens, Hanley. Index Test. (2nd ed.), p. 67, sp. 13, pl. 12, f. 13.

1857. Modiola arborescens, Reeve. Conch. Icon., vol. x., pl. 6, f .30.

1857. Perna arborescens, H. and A. Adams. Genera Rec. Moll., vol. ii., p. 516.

1878. Modiola arborescens, T. Woods. P.R.S. Tas., p. 55.

1862. Modiola arborescens, Chenu. Man. de. Conch., vol. ii., p. 154, f. 757.

1887. Modiola arborescens, Clessin. Conch. Cab. (ed. Kuster), p. 100, pl. 29, f. 10.

1891. Modiola arborescens, Tate. T.R.S. S.A., vol. xiv., p. 268.

1893. Modiola arborescens, Brazier. P.L.S. N.S.W. (2nd ser.), vol. viii., pt. 3, pp. 434, 435.

1902. Modiola arborescens, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 311.

Hab.—Dredged 6 to 8 fathoms off Rhyll, Western Port.

MODIOLA VEXILLUM, Reeve.

Volsella picta, Dunker m.s. (non Lamarck).

1857. Modiola vexillum, Reeve. Conch. Icon., vol. x., pl. 8, f. 40.

1889. Modiola vexillum, Clessin. Conch. Cab. (ed. Kuster), p. 125, No. 53, pl. 25, f. 12.

1901. Modiolaria vexillum, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 438.

Hab.—Port Melbourne.

MODIOLA VICTORIAE, Pritchard and Gatliff.

1903. Modiola victoriae, Pritchard and Gatliff. P.R.S. Vic., vol. xvi. n.s., pt. 1, p. 93, pl. xv., f. 1, 2.

Hab.—Dredged alive from about 6 fathoms off Rhyll, Phillip Island, Western Port.

Obs.—A species characterised by its regular tumidity and remarkably uniform height.

Genus **Modiolaria**, Loven, 1846.

MODIOLARIA IMPACTA, Herman.

Mytilus impacta, Herman. Naturforscher, vol. xvii., pl. 3, f. 5-8.

Modiola discors, Lamarck. Encyc. Meth., pl. 204, f. 5a, b.

1819. Modiola discors, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 114, No. 16.

1825. Mytilus impactus, Wood. Index. Test., p 59, No. 40, pl. 12, f. 40.

1836. Modiola discors, Lamarck. Anim. S. Vert. (2nd ed. Desh.), vol. vii., p. 23, No. 16.

1839. Modiola discors, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. iii., p. 13, No. 16.

1843. Modiola impacta, Hanley. Cat. Rec. Biv. Shells, p. 241.

1857. Modiola impacta, Reeve. Conch. Icon., vol. x., sp. 50, pl. 9, f. 64.

1873. Crenella discors, Hutton. Cat. Moll. N.Z., p. 78, No. 101.

1880. Crenella impacta, Hutton. Man. N.Z., Moll., p. 168.

1884. Modiola impacta, Tryon. Struct. and Syst. Conch., vol. iii., p. 264, pl. 128, f, 99.

1889. Modiolaria impacta, Clessin. Conch. Cab. (ed. Kuster), p. 147, No. 10, pl. 34, f. 9.

Hab.—San Remo.

MODIOLARIA BARBATA, Reeve.

1858. Lithodomus barbatus, Reeve. Conch. Icon., vol. x., No. 27, pl. 5, f. 27.

1858. Lithodomus laniger, Reeve. Id., f. 30.

1867. Modiolaria barbata, Angas. P.Z.S. Lond., p 911, pl. 44, f. 12.

1867. Crenella (Modiolaria) barbata, Angas. Id., p. 929, No. 108.

1878. Crenella barbata, Angas. Id., p. 871, No. 69.

1883. Modiolaria barbata, Brazier. P.L.S. N.S.W., vol. viii., p. 233.

1885. Modiolaria lanigera, E. A. Smith. Chall. Zool., vol. xiii., p. 278.

1894. Modiolaria barbata, Brazier. Id. (2nd ser.), vol. ix., p. 181, No. 149.

Hab.—San Remo; Ocean Beach, Point Nepean.

MODIOLARIA PAULUCCIAE, Crosse.

1863. Crenella paulucciae, Crosse. Jour. de. Conch, p. 89, pl. 1, f. 8.

1887. Modiolaria paulucciae, Tate. T.R.S. S.A., vol ix., p. 106, No. 149.

Hab.—Ocean Beach, Point Nepean.

MODIOLARIA CUNEATA, Gould.

1861. Modiolaria cuneata, Gould. Proc. Bost. Soc. Nat. Hist., vol. viii., p. 38.

1885. Modiolaria cuneata, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, p. 278, pl. 16, f. 7, 7a.

Hab.—Common Port Phillip, associated with tunicates, Carrum to Frankston. Portsea.

Family PHILOBRYIDAE.

Genus **Philobrya**, Carpenter.

PHILOBRYA CRENATULIFERA, Tate.

1892. Myrina crenatulifera, Tate. T.R.S. S.A., vol. xv., pt. 2, p. 131, pl. 1, f. 11, 11a.
1898. Philobrya crenulatifera, Tate. Id., vol. xxii., pt. 2, p. 87.
1901. Philobrya crenatulifera, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 439.
1902. Philobrya crenatulifera, Hedley. Id., vol. xxvii., pt. 1, p. 17.

Hab.—Type from South Australia (coll. by A. Adcock, probably in Tate Collection), Victoria, Barwon Heads (T. S. Hall); Flinders, Western Port (G. B. Pritchard), not Flinders Island, as recorded by Professor R. Tate.

PHILOBRYA FIMBRIATA, Tate.

1898. Philobrya fimbriata, Tate. T.R.S. S.A., vol. xxii., pt. 2, p. 87, pl. 4, f. 8.

Hab.—Victoria, dredged seven to nine fathoms at Port Phillip Heads by the late J. Bracebridge Wilson. (In Tate Collection.)

PHILOBRYA, sp.

Hab.—Western Port.

Family PTERIIDAE.

Genus **Pteria**, Scopoli, 1777.

PTERIA PAPILIONACEA, Lamarck.

Avicula papilionacea, Lamarck. Encyc. Meth., pl. 177, f. 5.
1819. Avicula papilionacea, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 149, No. 10.

1835. Avicula georgiana, Quoy and Gaimard. Astrolabe, Zool., vol. iii., p. 457, pl. 77, f. 10, 11.

1836. Avicula papilionacea, Lamarck. Anim. S. Vert., (2nd. ed. Desh.), vol. vii., p. 100, No. 10.

1839. Avicula papilionacea, Lamarck. Id., Anim. S. Vert. (3rd ed. Deshayes and Edwards), vol. iii., p. 40, No. 10.

1843. Avicula papilionacea, Hanley. Cat. Rec. Biv. Shells, p. 262.

1843. Avicula georgina, Hanley. Id., p. 263.

1857. Avicula rutila, Reeve. Conch. Icon., vol. x., pl. 8, f. 19.

1857. Avicula pulchella, Reeve. Id., f. 22.

1857. Avicula scalpta, Reeve. Id., pl. 11, f. 38.

1857. Avicula punctulata, Reeve. Id., pl. 12, f. 42.

1865. Avicula scalpta, Angas. P.Z.S. Lond., p. 654, No. 74.

1865. Avicula pulchella, Angas. Id., No. 75.

1865. Avicula rutila, Angas. Id., No. 76.

1865. Avicula punctulata, Angas. Id., No. 77.

1867. Avicula pulchella, Angas. Id., p. 930, No. 113.

1878. Avicula pulchella, T. Woods. P.R.S. Tas., p. 55.

1887. Avicula georgiana, Tate. T.R.S. S.A., vol. ix., p. 107, No. 153.

1897. Avicula papilionacea, Tate. Id., vol. xxi., pt. 1, p. 49.

1901. Pteria papilionacea, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 439.

Hab.—Very common along the coast, generally attached to seaweed.

Genus **Meleagrina**, Lamarck, 1799.

MELEAGRINA MARGARITIFERA, Linnaeus.

Mytilus margaritiferus, Linnaeus. Syst. Nat., p. 1153, pl. 221, f. 56.

1819. Meleagrina margaritifera, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 151, No. 1.

1825. Mytilus margaritiferus, Wood. Index Test., p. 56, pl. 12, f. 4.

1835. Meleagrina margaritifera, Lamarck. Anim. S. Vert. (2nd ed. Desh.), vol. vii., p. 107, No. 1.

1839. Meleagrina margaritifera, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. iii., p. 43, No. 1.

1843. Meleagrina margaritifera, Hanley. Cat. Rec. Biv. Shells, p. 264.

1865. Margaritifera margaritifera, Angas. P.Z.S. Lond., p. 654, No. 78.

1887. Meleagrina margaritifera, Tate. T.R.S. S.A., vol. ix., p. 107, No. 154.

Hab.—Barwon Heads (T. S. Hall).

Genus **Vulsella**, Lamarck, 1799.

VULSELLA LINGULATA, Lamarck.

1819. Vulsella lingulata, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 221.

1819. Vulsella ovata, Lamarck, Id., p. 222, No. 6.

Vulsella lingulata, Sowerby. Genera, vol. i., plate and figure.

1825. Ostrea vulsella, Wood. Index Test., p. 53, pl. 11, f. 84.

1827. Vulsella lingulata, Crouch. Intro. Lamarck's Conch., p. 21.

1828. Vulsella lingulata, Wood. Index Test., app. p. 59.

1836. Vulsella lingulata, Lamarck. Anim. S. Vert. (2nd ed. Desh.), vol. vii., p. 267, No. 1.

1836. Vulsella ovata, Lamarck. Id., p. 268, No. 6.

1839. Vulsella lingulata, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. iii., p. 99, No. 1.

1839. Vulsella ovata, Lamarck. Id., p. 100, No. 6.

1856. Vulsella lingulata, Hanley. Cat. Rec. Biv. Shells, p. 310.

1856. Vulsella ovata, Hanley. Id., pp. 311, 389, pl. 24, f. 49.

1858. Vulsella tasmanica, Reeve. Conch. Icon., vol. xi., pl. 1, f. 3.

1858. Vulsella limaeformis, Reeve. Id., pl. 2, f. 10a, b.
1858. Vulsella rudis, Reeve. Id., pl. 2, f. 12.
1878. Vulsella tasmanica, T. Woods. P.R.S. Tas., p. 55.
1887. Vulsella ovata, Tate. T.R.S. S.A., vol. ix., p. 107, No. 152.
1899. Vulsella lingulata, Melville and Standen. Jour. Lin. Soc. Lond., p. 184, No. 279.

Hab.—Western Port; Port Phillip; Polwarth coast; C. Otway; Warrnambool; Portland (Maplestone).

Genus Malleus, Lamarck, 1799.

MALLEUS ALBUS, Lamarck.

1819. Malleus albus, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 144, No. 1.
1836. Malleus albus, Lamarck. Id. (2nd ed. Desh.), vol. vii., p. 91, No. 1.
1839. Malleus albus, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. iii., p. 37, No. 1.
1843. Malleus albus, Hanley. Cat. Rec. Biv. Shells, p. 260.
1856. Malleus albus, Hanley. Id., p. 388, pl. 24, f. 38.
1858. Malleus albus, Reeve. Conch. Icon., vol. xi., pl. 1, f. 1.

Hab.—Gippsland coast (T. Worcester).

Obs.—We think it probable that this is the shell regarded by Professor Tate as M. vulsellatus, Lamarck, which he regards as correctly named for South Australian examples. Should this be so, numerous synonyms will have to be taken into consideration under the above species, M. albus, Lamarck.

Family PINNIDAE.

Genus Pinna, Linnaeus, 1758.

PINNA TASMANICA, T. Woods.

1876. Pinna tasmanica, T. Woods. P.R.S. Tas., p. 161.

1885. Pinna tasmanica, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, p. 33.

1901. Pinna tasmanica, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 1, p. 440.

Hab.—Off East Moncoeur Islands, Bass Straits, in 38 fathoms sand and shells (Challenger). Off Lakes Entrance (T. S. Hart). Western Port. Off Sorrento, Port Phillip.

Family SPONDYLIDAE.

Genus **Spondylus**, Linnaeus, 1758.

SPONDYLUS TENELLUS, Reeve.

1856. Spondylus tenellus, Reeve. Conch. Icon., vol. ix., pl. 18, f. 67.

1878. Spondylus tenellus, T. Woods. P.R.S. Tas., p. 57.

1887. Spondylus tenellus, Tate. T.R.S. S.A., vol. ix., p. 109, No. 164.

1901. Spondylus tenellus, Tate and May, P.L.S. N.S.W., vol. xxvi., pt. 3, p. 440.

Hab.—Western Port. Portland (Maplestone), Phillip Island (Nat. Mus.).

Family LIMIDAE.

Genus **Lima**, Bruguière, 1792.

LIMA MULTICOSTATA, Sowerby.

1843. Lima multicostata, Sowerby. Thes. Conch., vol. i., p. 85, sp. 6., pl. 22, f. 38.

1843. Lima multicostata, Hanley. Cat. Rec. Biv. Shells, p. 266.

1865. Radula lima, Angas. P.Z.S. Lond., p. 656, No. 91.

1872. Lima multicostata, Sowerby in Reeve. Conch. Icon., vol. xviii., pl. 1, f. 4.

1878. Radula lima, T. Woods. P.R.S. Tas., p. 56.

1885. Lima multicostata, E. A. Smith. Chall Zool., vol. xiii., Lamelli, p. 288.

1887. Lima multicostata, Tate. T.R.S. S.A., vol. ix., p. 108, No. 160.

1901. Lima multicostata, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 440.

1902. Lima lima var. multicostata, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 309.

Hab.—Cowes, Western Port.

LIMA (LIMATULA) BULLATA, Born.

1780. Ostrea bullata, Born. Mus. Caes. Vindobon, p. 110, pl. 6, f. 8.

1817. Ostrea bullata, Dillwyn. Desc. Cat., p. 270.

1843. Lima bullata, Sowerby. Thes. Conch., vol i., p. 84, pl. 20, f. 32, 33.

1843. Lima bullata, Hanley. Cat. Rec. Biv. Shells, p. 266.

1865. Radula (Limatula) bullata, Angas. P.Z.S. Lond., p. 656, No. 93.

1872. Lima bullata, Sowerby in Reeve. Coch. Icon., vol. xviii., pl. 1, f. 3a, b.

1872. Lima strangei, Sowerby. Id., pl. iii., f. 15.

1884. Lima (Limatula) bullata, Tryon. Struct. and Syst. Conch. vol. iii., p. 287, pl. 132, f. 93.

1885. Lima (Limatula) bullata, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, p. 292.

1887. Lima bullata, Tate. T.R.S. S.A., vol. ix., p. 109, No. 162.

1901. Lima (Limatula) bullata, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 440.

1902. Lima bullata, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 310.

Hab.—Dredged alive off Rhyll, Western Port. Portsea to Rye, Port Phillip. Off E. Moncoeur Island, Bass Strait (Challenger).

LIMA, sp.

Hab.—Port Fairy, and San Remo.

Obs.—This species we have not yet been able to identify.

Family Anomiidae.

Genus Placunanomia, Brodrip, 1832.

Placunanomia ione, Gray.

1849. Placunanomia ione, Gray. P.Z.S. Lond., p. 123.
1850. Placunanomia, ione, Gray. B.M. Cat. Biv. Moll., pt. 1, p. 13, No. 10.
1859. Placunanomia ione, Reeve. Conch. Icon., vol. xi., pl. 2, f. 6a, b, c.
1867. Placunanomia (Monia) ione, Angas. P.Z.S. Lond., p. 933, No. 132.
1873. Placunanomia ione, Hutton. Cat. Mar. Moll. N.Z., p. 84.
1880. Placunanomia ione, Hutton. Man. N.Z., Moll., p. 174.
1886. Placunanomia ione, Tate. T.R.S. S.A., vol. viii., p. 101.
1887. Placunanomia ione, Tate. Id., vol. ix., p. 109, No. 165.

Hab.—Western Port.

Family Pectenidae.

Genus Pecten, Lamarck, 1799.

Pecten medius, Lamarck.

1819. Pecten medius, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 163, No. 2.
1835. Pecten laticostatus, Gray (non Lamarck). Yate's New Zealand, p. 310.
1836. Pecten medius, Lamarck. Anim. S. Vert. (2nd ed. Desh.), vol. vii., p. 130, No. 2.
1839. Pecten medius, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. iii., p. 51, No. 2.
1842. Pecten fuscus, Sowerby. Thes. Conch., vol. i., p. 47, pl. 16, f. 118, 119.
1842. Pecten medius, Sowerby. Id., pl. 15, f. 102-104, pl. 18, f. 117, 118.

1843. Pecten laticostatus, Gray (non Lamarck), in Dieffenbach's New Zealand, vol. ii., p. 260.
1852. Pecten fumatus, Reeve. Conch. Icon., vol. viii., pl. 7, f. 32.
1852. Pecten novaezelandiae, Reeve. Id., pl. 8, f. 36.
1852. Pecten filosus, Reeve. Id., pl. 11, f. 42.
1852. Pecten medius, Reeve. Id., pl. 11, f. 44.
1856. Pecten laticostatus, Hanley (non Lamarck). Cat. Rec. Biv. Shells, p. 287.
1865. Vola laticostata, Angas. P.Z.S. Lond., p. 656, No. 90.
1867. Vola fumata, Angas. P.Z.S. Lond., p. 933, No. 129.
1880. Pecten laticostatus, Hutton (non Lamarck). Man. N.Z., Moll., p. 171.
1885. Pecten (Janira) fumatus, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, p. 307.
1887. Pecten meridionalis, Tate. P.R.S. Tas., p. 114.
1887. Pecten fumatus, var albus, Tate. Id., p. 113.
1902. Pecten medius, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, pp. 303, 304.

Hab.—Common on weedy banks, Port Phillip and Western Port. Gippsland coast.

Obs.—Pecten bifidus (Menke, Moll. Nov. Holl., p. 35) we have omitted from the above, as we believe that it falls in with P. modestus, Reeve, which on the material at present available to us, we retain as a distinct species. Hanley as far back as 1856, in his Catalogue of Recent Bivalve Shells, page 287, suggests that P. laticostatus, Gray, P. bifidus, and P. medius are one and the same, for he states, "P. laticostatus, Gray, is the bifidus of Phillippins Conchylien, and judging from the description of Deshayes in the third vol. of the Encyc. Methodique, the medius of Lamarck." G. F. Angas also has remarked on the close alliance between Pecten laticostatus, Gray,, and P. medius, Lamarck, in his reference, which we quote above. Perry's P. concavum (Conchology, pl. 55, f. 1), may probably represent this species, in which case his name has priority, but his specimen is recorded as from the Red Sea, and his figure is too unsatisfactory for definite determination.

Genus **Chlamys**, Bolten, 1798.

CHLAMYS UNDULATUS, Sowerby.

1842. Pecten undulatus, Sowerby. Thes. Conch., vol. i., p. 60, pl. 19, f. 206, 207.

1843. Pecten undulatus, Hanley. Cat. Rec. Biv. Shells, p. 276.

1853. Pecten undulatus, Reeve. Conch. Icon., vol. viii., pl. 20, f. 73.

1876. Pecten mariae, T. Woods. P.R.S. Tas., p. 158.

1886. Pecten undulatus, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, p. 299.

1901. Pecten undulatus, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 441.

Hab.—Off East Moncoeur Island, Bass Strait, in 38 fathoms (Challenger). Port Albert. Dredged off Rhyll, Western Port. Port Phillip Bay (R. Tate).

CHLAMYS BIFRONS, Lamarck.

1819. Pecten bifrons, Lamarck. Anim. S. Vert., vol. vi., pt. 1,, p. 164, No. 4.

1836. Pecten bifrons, Lamarck, Id. (2nd ed. Desh.), vol. vii., p. 131, No. 4.

1839. Pecten bifrons, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. iii., p. 51, No. 4.

1841. Pecten bifrons, Delessert. Recueil de Coq., pl. 15, f. 5a, b. c.

1842. Pecten bifrons, Sowerby. Thes. Conch., vol i., p. 54, No. 26, pl. 12, f. 9, 10.

1843. Pecten bifrons, Hanley. Cat. Rec. Biv. Shells, p. 273.

1853. Pecten bifrons, Reeve. Conch. Icon., vol. viii., pl. 12, f. 45.

1863. Pecten tasmanicus, Adams and Angas. P.Z.S. Lond., p. 428, No. 13, pl. 37, f. 21a, b.

1865. Pecten (Chlamys) bifrons, Angas. P.Z.S. Lond., p. 656, No. 89.

1887. Pecten bifrons, Tate. T.R.S. S.A., vol. ix., p. 108, No. 158.

1901. Pecten bifrons, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 440.

Hab.—San Remo, Western Port. Portland (Maplestone).

Obs.—This species shows considerable variation, and we think it probable that a full series will necessitate the inclusion with it of the foregoing species, P. undulatus, for both P. tasmanicus, Adams and Angas, and P. mariae, T. Woods, show such intermediate characters as to point strongly in this direction.

CHLAMYS ASPERRIMUS, Lamarck.

1819. Pecten asperrimus, Lamarck. Anim. S. Vert., vol. vi., pt. 1, p. 174, No. 43.

1828. Ostrea asperrimus, Wood. Index Test. Sup., p. 47, pl. 2, f. 1.

1836. Pecten asperrimus, Lamarck. Anim. S. Vert. (2nd ed. Desh.), vol. vii., p. 145, No. 43.

1839. Pecten asperrimus, Lamarck. Id. (3rd ed. Deshayes and Edwards), vol. iii., p. 56, No. 43.

1841. Pecten asperrimus, Delessert. Recueil de Coq., pl. 15, f. 1a, b.

1842. Pecten asperrimus, Sowerby. Thes. Conch., vol. i., p. 75, No. 94, pl. 17, f. 156-158.

1842. Pecten australis, Sowerby. Id., p. 76, pl. 19, f. 210, 220.

1843. Pecten asperrimus, Hanley. Cat. Rec. Biv. Shells, p. 284.

1843. Pecten australis, Hanley. Id., p. 285.

1853. Pecten asperrimus, Reeve. Conch. Icon., vol. viii., pl. 20, f. 75.

1853. Pecten australis, Reeve. Id., pl. 25, f. 103a, b.

1865. Pecten australis, Angas. P.Z.S. Lond., p. 656, No. 88.

1878. Pecten asperrimus, T. Woods. P.R.S. Tas., p 56.

1880. Pecten australis, Hutton. Man. N.Z., Moll. p. 171.

1885. Pecten asperrimus, E. A. Smith. Chall. Zool., vol. xiii., Lamelli, p. 294.

1887. Pecten asperrimus, Tate. T.R.S. S.A., vol. ix., p. 108, No. 155.

Hab.—Coast generally, our commonest species.

Obs.—Menke in his Moll. Nov. Holl., p. 36, gives priority to P. rubidus, Marytn, for this species, and refers to Univ. Conch., vol. 4, pl. 133, fig. sinistr., but we have been unable to gain access to this work, and cannot therefore at present decide the point. We think it likely that P. sentis, Reeve, Conch. Icon., vol. viii., pl. 29, f. 125, represents a young specimen of P. asperrimus.

CHLAMYS AKTINOS, Petterd.

1886. Pecten aktinos, Petterd. P.R.S. Tas., p. 320.

1887. Pecten bednalli, Tate. T.R.S. S.A., vol. ix., p. 73, pl. 4, f. 3.

1900. Chlamys bednalli, Hedley. P.L.S.N.S.W., vol. xxv., pt. 3, p. 495, pl. 25, f. 10-13.

1901. Pecten actinos, Tate and May. Id., vol. xxvi., pt. 3, p. 441.

Hab.—Sorrento, Port Phillip; Storeham, and dredged off Rhyll. Western Port.

CHLAMYS HEDLEYI, Dautzenberg.

1900. Chlamys fenestrata, Hedley (non Forbes). P.L.S. N.S.W.. vol. xxv., pt. 4, p. 730, pl. 48, f. 17 19.

1901. Chlamys hedleyi, Dautzenberg. Jour. de Conch., vol. xlix., p. 348.

1902. Chlamys fenestrata, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 307.

Hab.—Ocean Beach, Point Nepean; Torquay.

Obs.—The specimens of this species we have hitherto obtained are all small young shells, and have been identified for us by Mr. Hedley as the young of his species.

Genus **Cyclopecten**, Verrill.

CYCLOPECTEN NEPEANENSIS, Pritchard and Gatliff.

1904. Cyclopecten nepeanensis, Pritchard and Gatliff. [See Article XI., pl. 20, f. 5, of this present volume].

Hab.—Ocean Beach, Point Nepean.

Obs.—A very small translucent shell.

Genus **Amussium**, Schumacher.

AMUSSIUM THETIDIS, Hedley.

1902. Amusium thetidis, Hedley. Mem. Austr. Mus., vol. iv., pt. 5, p. 304, f. 49.

Hab.—Ocean Beach, Point Nepean.

Obs.—One valve only obtained, and submitted to Mr. Hedley for comparison with the type of A. thetidis; he considers it to be the same species.

Family OSTREIDAE.

Genus **Ostrea**, Linnaeus, 1758.

OSTREA ANGASI, Sowerby.

1871. Ostrea angassi, Sowerby, in Reeve. Conch. Icon., vol. xviii., pl. 13, f. 27, erroneously numbered 28.

1878. Ostrea angasi, T. Woods. P.R.S. Tas., p. 56.

1886. Ostrea angasi, Tate. T.R.S. S.A., vol. ix., p. 110. No. 166.

1901. Ostrea angasi, Tate and May. P.L.S. N.S.W., vol. xxvi., pt. 3, p. 441.

Hab.—Western Port; Port Phillip; Port Albert.

Obs.—This species occurs commonly in the old beach deposits of Port Phillip, also in the Pleistocene beds of West Melbourne.

Art. VIII.—*Fossil Fish Remains from the Tertiaries of Australia.*

Part I.

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and

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(With Plates XI. and XII.).

[Read 14th July, 1904].

Contents.

I.—INTRODUCTION.

Fish remains form a very considerable portion of the fossil fauna of the Australian Tertiary deposits, but hitherto they appear to have been somewhat neglected. The previously recorded species are principally to be found in lists and catalogues of fossils, but seldom more than as a mere identification. Two of our species have, however, been well figured and described by the late Sir F. McCoy in the Prodromus of the Palaeontology of Victoria, and one other species by the late

Professor Ralph Tate in the Proceedings of the Royal Society of New South Wales. The majority of the species identified in this paper are new to Australia, though some have previously been recorded from New Zealand deposits. In some cases we feel assured that the earlier records are not always to be relied upon in view of the large amount of material we have had at our disposal.

The following have been previously recorded from the Australian Tertiaries:—

Strophodus eocenicus	= Asteracanthus eocaenicus.
Otodus desori	= Oxyrhina desori.
Lamna elegans	= Lamna crassidens.
Lamna contortidens	= Odontaspis contortidens.
Lamna denticulata	= Lamna compressa.
Oxyrhina trigonodon	= Oxyrhina hastalis.
Oxyrhina hastalis.	
Oxyrhina woodsii	= Lamna apiculata.
Carcharodon angustidens	= Carcharodon auriculatus.
Carcharodon megalodon.	

In working out the material herein dealt with, we have fully examined the collections in the National Museum and that made by one of us (G. B. Pritchard), and we are also indebted to the following gentlemen for the loan of specimens from their collections:—Messrs. J. R. Dixon, T. S. Hall, J. F. Mulder, F. Spry, and G. Sweet, to whom we desire to express our thanks.

The present paper contains references to eleven genera, representing twenty-five species of the Selachian group, and includes three new species. The remainder of the fish fauna we hope to deal with in another paper.

II.—DESCRIPTION OF SPECIES.

Order SELACHII.

Family *Notidanidae.*

Genus, *Notidanus*, Cuvier.

Notidanus jenningsi, sp. nov. (Pl. XI., Figs. 1, 2).

Description.—Small portion of the lower jaw partially enveloped in a phosphatic nodule bearing two anterior medial teeth and imperfect traces of others in the same parallel series.

The teeth preserved apparently belong to the left side of the lower jaw and represent two of the principal teeth. Each tooth is characterised by a marked anterior fold situated at about one-third the length of the tooth from the front; the anterior tooth has a very strong and broad main cusp which bears very fine serrations, the serrations of the basal part of the crown being much coarser and not a graduated series, but irregular in strength; the anterior slope of the adjoining tooth is finely, deeply and more regularly serrate; the posterior portion is wanting.

Dimensions.—Length, 11.5 mm.; height from base of jaw, 7.5 mm. These measurements refer to the perfect tooth.

Locality and Horizon.—From nodule band at the base of the cliffs Beaumaris, Port Phillip. Collected and presented by the late Mr. W. B. Jennings (Nat. Mus. Coll.). From the good state of preservation of our specimen it apparently belongs to the Kalimnan Beds.

Observations.—The relationships of our species point in the direction of N. serratissimus, Agassiz, from the English Eocene of the Isle of Sheppey and Highgate; but in the fineness of its serrations it shows an approach to the Pliocene, N. gigas, on the one hand, and to the recent Indian grey shark, N. indicus, on the other.

This species we have named in honour of the late Mr. Jennings, who did an immense amount of work on these beds, though he appears to have received very little credit for his labours.

Family *Spinacidae*

Genus *Acanthias*, Risso.

Acanthias geelongensis, sp. nov. (Pl. XI., Fig. 15).

Description.—Tooth with a somewhat slender and recurved cusp; base prolonged anteriorly; with a posterior notch and one or two crenulae on the posterior part of the base behind the notch.

Dimensions.—Length at base of tooth, 6 mm.; height, 5 mm.

Observations.—This species bears certain resemblances to Acanthias orpiensis, Winkler sp. (27, Pl. I., Fig. 17, and 32, Pl.

I., Figs. 1 and 2). It differs, however, in having a more slender cusp and a lower and more elongate base.

Locality and Horizon.—Orphanage Hill, Geelong (T. S. Hall Coll.)[1]—Balcombian.

Family *Cestraciontidae.*

Genus *Cestracion*, Cuvier.

Cestracion cainozoicus, sp. nov. (Pl. XI., Figs. 5-8. Pl. XII., Fig. 2).

Description.—Various lateral teeth showing variation comparable with that of the crushing teeth of the recent C. philippi. In shape the specimens vary from almost semicircular through subrhomboidal to elongate-oblong; the latter form usually showing a stronger incurvation of the outer lateral edge. In the best preserved specimens the surface towards the outer lateral edges shows the submedian ridge as a fine elevated band from which proceed anastomosing ridges giving rise to the pitted appearance at the extremities of the teeth. The arrangement of the ridges running off the submedian ridge is generally parallel and at right angles to it. As in common with other Cestraciont teeth, the base of the outer concave side is usually excavate, giving rise to an articulating ridge at the junction of the crown with the root.

The surface of the crown is, generally speaking, strongly convex, and is apparently much smoother than that of the living species. An interesting point of agreement, however, is shown in one specimen which has flaked off superficially from the rest of the crown, a feature which may be readily tested in the living species.

Dimensions.—Specimen (a) (semicircular form)—Length, 13 mm.; breadth, 7 mm.; height, 5 mm.

Specimen (b) (subrhomboidal form)—Length, 18.5 mm.; breadth, 11 mm.; height, 7 mm.

Specimen (c) (elongate oblong form)—Length, 18 mm.; breadth, 7 mm.; height, 5 mm.

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1 Since presented to the National Museum.

Specimen (d)—Length, 26 mm.; breadth, 10 mm.; height, 7 mm.

Locality and Horizon.—From the nodule band at the base of the cliffs, Beaumaris, Port Phillip. National Museum Collection, collected by the late Mr. W. Kershaw, and the late Mr. W. B. Jennings; also in the private collections of Messrs. Dixon and G. B. Pritchard.

From the nodule band at the base of the upper beds Grange Burn, near Hamilton, Western Victoria. Nat. Mus. Coll., presented by Messrs. F. Spry and A. A. Kelley, also Coll. G. B. Pritchard.

The majority of the specimens hitherto obtained of this species have been from the Kalimnan Beds, but as many show considerable erosion it is probable that they may have been derived from the Balcombian. Curlewis; Beds, near Geelong (Nat. Mus. Collection, presented by A. C. Curlewis); Murgheboluc (T. S. Hall Coll.)—Balcombian.

Warranooke, 23 miles north of Stawell (Nat. Mus. Collection from Mines Department, 3502).—Barwonian.

Observations.—The genus itself has been previously recorded from our Tertiaries by Tate (25, p. 246), and by Hall and Pritchard (12, p. 304), but no described Australasian Tertiary species has hitherto been known. For confirmatory evidence of the generic affinities of our specimens thin slices of the teeth have been microscopically examined, and they show the irregular habit of the pulp-canals and the characteristic outspread canaliculi near the upper surface, a feature which we have also seen in actual recent specimens, and which has also been well illustrated by Owen in his Odontography (22).

The first European Tertiary record of Cestracion was made by Winkler (27, p. 17) from the Bruxellian (Middle Eocene) of Belgium, and subsequently by A. S. Woodward (32, pp. 6, 7, 13) from the London Clay (Lower Eocene).

Genus *Asteracanthus*, Agassiz.

Asteracanthus eocaenicus, Tate, sp. (Pl. XI., Figs. 3, 4. Pl. XII., Fig. 1).

Strophodus eocenicus, Tate, 1894. Proc. Roy. Soc. N.S.W., p. 169, pl. 13, f. 6.

Description.—According to Professor Tate, this "species is somewhat comparable with S. magnus, Agassiz, but is narrower with coarser reticulate rugosities and the inner margin is very finely reticulate-punctate; the outline is subtrapezoidal, about three times as long as wide, broader at one end, which is convexedly truncate and narrower at the other, which is truncated; uniformly depressedly convex above." This differs from Cestracion, amongst other points, in having a distinct articulating keel entirely round the tooth instead of on the outer side, and in the absence of the narrow submedian band on the upper surface. In the microscopical structure of the teeth there is also definite evidence of the affinity of this form with Asteracanthus, for in a vertical section the tubuli in the dentine layer are arranged in close more or less parallel bundles and quite distinctive from the structure seen in the teeth of Cestracion.

Dimensions.—Small specimen—Length, 17 mm.; breadth, 6.5 mm.; height, 2.5 mm.

Medium specimen—Length, 29 mm.; breadth, 11.5 mm.; height, 8 mm.

Large specimen—Length, 32.5 mm.; breadth, 11.5 mm.; height, 8.5 mm.

Locality and Horizon.—Geological Survey, T.M. 2. Limestone of the Moorabool Valley near Maude. Professor Tate's figured specimen is recorded as from Cheltenham, Port Phillip, i.e., Beaumaris. He also mentions its occurrence in "Lower Murravian," and refers to a specimen in Mr. Sweet's collection from the limestones of the Moorabool River.[1]

Observations.—The teeth of Asteracanthus are decidedly rarer in our Cainozoic Beds than Cestracion, but, judging from Professor Tate's remark, "fish-plates, which are not of uncommon occurrence at Cheltenham," he appears to have included Cestracion as referable to Strophodus. Strophodus, however, has been displaced in favour of Asteracanthus, and is now regarded as a synonym. The structure of the teeth of the above species is very distinct from that of Cestracion, as will be seen from the photograph, Pl. XII., Fig. 1.

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[1] This specimen has been since presented to the National Museum by Mr. Sweet.

Family *Carchariidae.*

Genus *Galeocerdo*, Müller and Henle.

Galeocerdo davisi, nom. mut.

Notidanus marginalis, Davis, 1888. Trans. Roy. Dublin Soc., ser. 2, vol. iv., p. 34, pl. 6, f. 7 (non. f. 8).

Galeocerdo sp., A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. 1, p. 167.

Locality and Horizon.—Clays of the coastal sections near the Gellibrand River (Pritchard Coll.), 3 miles west of the mouth of the Gellibrand River (Geol. Surv. Vict., A.W. 9, Nat. Mus. Coll.).—Balcombian.

Grange Burn, near Hamilton (presented by A. A. Kelley, Esq., Nat. Mus. Coll.; also Pritchard Coll.). Beaumaris, Port Phillip (Dixon Coll.; Pritchard Coll.; Nat. Mus. Coll., presented by the late Mr. W. B. Jennings).—Kalimnan; but as mostly worn probably derived from the Balcombian.

Observations.—This species was first figured and described by Davis under the generic name of Notidanus, but, as was subsequently pointed out by A. S. Woodward (30, p. 167), Davis included a tooth of Galeocerdo with his Notidanus, and as the specific name marginalis has been retained for Davis' Notidanus by A. S. Woodward, the Galeocerdo before us may be conveniently referred to as G. davisi.

This present form is somewhat intermediate between G. latidens, Ag., and G. aduncus, Ag., the somewhat depressed cusp reminding us of the former and the heavy base of the latter species; a good distinctive character of G. davisi seems to be the marked regularity of the posterior slope. This form was originally recorded by Davis from the Waipara and the Oamaru Formations of New Zealand and regarded as equivalent to Upper Cretaceous and Oligocene respectively.

Galeocerdo latidens, Agassiz.

Galeocerdo latidens, Agassiz, 1843. Poiss. Foss., vol. iii., p. 231, pl. 26, figs. 22, 23.

Galeocerdo latidens, Ag., Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. 1, p. 444.

Locality and Horizon.—Grange Burn, near Hamilton (Pritchard Coll.). Kalimnan apparently derived from Balcombian. Beaumaris Port Phillip. (Nat. Mus. Coll., presented by the late Mr. W. B. Jennings; also Pritchard Coll.).—Kalimnan, apparently also derived from Balcombian.

Observations.—A comparatively rare form in our beds, the commonest form being G. davisi, but it may be picked out by its more depressed character and narrow elongated root. This is a widely-distributed form occurring in various parts of Europe, North America, and Egypt, in beds of Eocene Age.

Galeocerdo aduncus, Agassiz.

Galeocerdo aduncus, Agassiz, 1843. Poiss. Foss., vol. iii., p. 231, pl. 26, figs. 24-28.

Galeocerdo aduncus, Ag., Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. 1, p. 444.

Locality and Horizon—Beaumaris, Port Phillip (Dixon Coll., Nat. Mus. Coll., presented by the late Mr. W. B. Jennings). Kalimnan—one specimen in a good state of preservation, the other example in a worn condition.

Observations.—This species is also rare in our beds, but may be distinguished by its coarser serrations at the base of the cusp on the posterior side and the more erect and robust cusp. This has a wide geological range, being found in the Eocene, Miocene and Pliocene of Europe and North America.

Genus *Carcharias,* Cuvier.

Sub-genus, *Prionodon,* Müller and Henle.

Carcharias (Prionodon) acutus, Agassiz.

Carcharias acutus, Agassiz, 1843. Poiss. Foss., vol. iii., p. 242, pl. 36, f. 8, 9.

Locality and Horizon.—Waurn Ponds, near Geelong (Nat. Mus. Coll., purchased from Mr. J. F. Bailey).—Jan Jukian.

Observations.—The elongate and acute cusp with its lateral serrations places this form without much doubt under the above species, but unfortunately it is at present only represented by

one well-preserved specimen with part of the base wanting. This species was originally described from the Marly Chalk of Westphalia, and is Upper Cretaceous.

Genus, *Sphyrna*, Rafinesque.

Sphyrna prisca, Agassiz. (Pl. XI., Fig. 9).

Sphyrna prisca, Agassiz, 1843. Poiss. Foss., vol. iii., p. 234, pl. 26a, figs. 35-50.

Sphyrna prisca, Ag., A. S. Woodward, 1889. Cat. Foss. Fishes Brit. Mus., Nat. Hist., pt. 1, p. 453.

Locality and Horizon.—Orphanage Hill, Fyansford, Geelong (T. S. Hall Coll.)[1]—Balcombian.

Observations.—Although it is held that the separate teeth of Sphyrna and Carcharias are practically indistinguishable from one another, we have found it impossible to place our specimen under any other genus, as it agrees very closely with f. 50 of Agassiz's S. prisca. The measurement of our specimen from the top of the base to the apex is 5.5 mm. S. prisca is an Eocene and Miocene form, and is found in Europe and North America.

Family *Lamnidae.*

Genus *Odontaspis*, Agassiz.

Odontaspis contortidens, Agassiz.

Lamna (Odontaspis) contortidens, Agassiz, 1843. Poiss. Foss., vol. iii., p. 294,, pl. 37a, figs. 17-23.

Odontaspis contortidens, Ag., A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. 1, p. 366.

Locality and Horizon.—Lower Aldinga Beds (Pritchard Coll.); Spring Creek, or Bird Rock Bluff, near Geelong, lowest zone (Pritchard Coll.); Waurn Ponds, near Geelong (Nat. Mus. Coll., purchased from J. F. Bailey, also Pritchard Coll.); Coast Section, Castle Cove, near Aire River (Pritchard Coll.)—Jan Jukian.

Lower Beds at Muddy Creek (Pritchard Coll.); Moorabool Valley [Batesford?] F. Spry Coll..); Fyansford, near Geelong (J. F. Mulder).—Balcombian.

1 Since presented to the National Museum.

Belmont, near Geelong (J. F. Mulder).—Barwonian.

Grange Burn, Upper Beds (Nat. Mus. Coll., purchased from R. Lindsay; also presented by G. Robinson; also Spry Coll., and Pritchard Coll.); Beaumaris, Port Phillip (Dixon Coll; Pritchard Coll.; Nat. Mus. Coll., purchased from J. F. Bailey). —Kalimnan—all more or less worn, and therefore probably derived from Balcombian.

Observations.—This species was first recorded by the late Sir F. McCoy from "the Miocene of Victoria" in 1866 (15, p. 16). Authentic specimens of O. contortidens from the Lower Tertiary beds of Europe have assisted us towards this identification. The variations exhibited in the above series seem to be easily accounted for by the different positions which they occupied in the jaw. The species occurs in Europe and North America in strata of Eocene to Pliocene ages.

Odontaspis incurva, Davis, sp.

Lamna incurva, Davis, 1888. Trans. Roy. Dublin. Soc., ser. 2, vol. iv., p. 17, pl. 3, f. 2-5.

Odontaspis incurva, Davis, sp., A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. 1, p. 372.

Locality and Horizon.—Waurn Ponds (purchased J. F. Bailey, Nat. Mus. Coll., also Pritchard Coll.)—Jan Jukian.

Warranooke, 23 miles N. of Stawell (Nat. Mus. Coll. from Mines Dept., 3502).—Barwonian.

Grange Burn, Upper Beds (Pritchard Coll.). Beaumaris, Port Phillip (Nat. Mus. Coll., purchased from J. F. Bailey, Pritchard Coll.).—Kalimnan.

Observations.—This species may be distinguished from the foregoing O. contortidens, Ag., by its more robust crown, convex outer face, depressed and smooth inner surface, the former being of a more slender type with a convex and striated inner surface. This species was originally described from the Waipara and Oamaru formations, New Zealand, Upper Cretaceous and Oligocene respectively.

Odontaspis cuspidata, Agassiz, sp.

Lamna cuspidata, Agassiz, 1843. Poiss. Foss., vol. iii., p. 290, pl. 37a, figs. 43-50.

Odontaspis cuspidata, Ag., sp., A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. 1, p. 368.

Lamna marginalis, Davis, 1888. Trans Roy., Dublin Soc., ser. 2, vol. iv., p. 19, pl. 3, f. 8-10.

Locality and Horizon.—Clays of Cape Otway (Pritchard Coll.). Jan Jukian.

Black Beds east of Gellibrand River, A.W. 7, Geo. Surv., Vic. (Nat. Mus. Coll.)—Balcombian.

Beaumaris, Port Phillip. (Nat. Mus. Coll., purchased from J. F. Bailey, also Dixon Coll.) Grange Burn (Pritchard Coll.). —Kalimnan (? derived).

Observations.—The teeth of this species are generally of an oblique habit, and probably include the forms figured by Agassiz under the names of hopei, dubia, and ferox. This species has been found in Europe and North America, and occurs in Eocene and Miocene formations. Also from the Waipara and Oamaru formations, New Zealand, Upper Cretaceous and Oligocene, under the name of L. marginalis, Davis.

Odontaspis attenuata, Davis, sp. (Pl. XI., Figs. 10, 11).

Lamna attenuata, Davis, 1888. Trans. Roy. Dublin Soc., ser. 2, vol. iv., p. 19, pl. 3, f. 11a-c.

Locality and Horizon.—Lower beds of the Aldinga series, South Australia (Pritchard Coll.). Waurn Ponds (Nat. Mus. Coll., purchased from J. F. Bailey).—Jan Jukian.

Belmont (J. F. Mulder Coll.).—Barwonian.

Beaumaris, Port Phillip (Nat. Mus. Coll., purchased from J. F. Bailey).—Kalimnan.

Observations.—The original specimens were described from teeth wanting the base. One of our specimens is fortunately well preserved, and shows that the root is strong and bifid with a well-marked median canal at the base of the crown. As the majority of the specimens show merely the crown, there appears to be a definite plane of weakness between the crown and the root. This specie somewhat resembles O. contortidens, Ag., in having a striated inner coronal face, but these striations in the latter are fewer and more or less parallel, whilst in the former they are closer together, and have a tendency to coalesce. Another distinguishing feature is the very slender habit of O. attentuata, Ag.

Hitherto known only from the Oamaru formation, New Zealand—Oligocene.

Genus *Lamna*, Cuvier.

Lamna crassidens, Agassiz.

Lamna crassidens, Agassiz, 1843. Poiss. Foss., vol. iii., p. 292, pl. 35, figs. 8-21.

Odontaspis (?) crassidens, Ag. sp., A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist.,pt. i., p. 373.

Locality and Horizon.—Bird Rock Bluff, Spring Creek, near Geelong (Pritchard Coll.); Waurn Ponds (J. F. Mulder Coll.).—Jan Jukian.

Balcombe's Bay (Nat. Mus. Coll., collected by W. Kershaw; also Pritchard Coll.); Muddy Creek (Nat. Mus. Coll.).—Balcombian.

Observations.—This species is recorded from the Eocene of Europe and North America and the Miocene of Germany.

Lamna apiculata, Agassiz, sp.

Otodus apiculatus, Agassiz, 1843. Poiss. Foss., vol. iii., p. 275, pl. 32, figs. 32-35.

Oxyrrhinus woodsii, McCoy, MS., T. Woods, 1862. Geo. Obs. S.A., p. 80, 2 figures.

Oxyrhina enysii, Davis, 1888. Trans. R. Dubl. Soc., ser. 2, vol. iv., p. 28, pl. v., figs. 17a-c, 18, 19, 20.

Oxyrhina subvexa, Davis, 1888, ibid., p. 31, pl. vi., figs. 4a-c.

Locality and Horizon.—Waurn Ponds, near Geelong (Nat. Mus. Coll., purchased from J. F. Bailey); Pritchard Coll.; Mulder Coll.—Jan Jukian.

Lower Beds of Muddy Creek (Pritchard Coll.); Balcombe's Bay (Pritchard Coll.); Gellibrand coast section (Pritchard Coll.)—Balcombian. 9 miles west of Casterton (Nat. Mus. Coll., from Mines Department, No. 3493).—Barwonian.

Grange Burn (Spry Coll.).—Beaumaris (Dixon Coll.).—Kalimnan, all worn and probably derived from the Balcombian.

Observations.—This species usually shows a backward curvature, and in the series before us the posterior teeth show a much stronger lateral curvature. Perfect specimens showing the

lateral denticles well-preserved are comparatively rare; the most usual condition in which they are found exhibits merely the smooth portion of the crown. This would account for Davis placing his specimens in the genus Oxyrhina. Agassiz records this species from the Tertiary of Véteuil (or Verteuil), Charente, France.

The New Zealand representatives are from the Waipara and Oamaru formations—i.e., Upper Cretaceous and Oligocene respectively.

Lamna compressa, Agassiz.

Lamna compressa, Agassiz, 1843. Poiss. Foss., vol. iii., p. 290, pl. xxxvii., a. figs. 35-42.

Lamna macrota, Ag. (vel compressa), A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. 1, p. 402.

Lamna marginalis, Davis, 1888. Trans. Roy. Dublin Soc., ser. 2, vol. iv., p. 19, pl. 3, figs. 8-10.

Locality and Horizon.—Table Cape (Nat. Mus. Coll., presented by the Rev. Mr. Legge).—Jan Jukian.

Warranooke, 23 miles north of Stawell (Nat. Mus. Coll., from Mines Dept., 3502).—Barwonian.

Grange Burn (Nat. Mus. Coll., purchased from R. Lindsay). Beaumaris, Port Phillip (Pritchard Coll.).—Kalimnan (worn specimens only).

Observations.—The European specimens referable to Lamna compressa are said to show a range of form embracing the type of L. macrota, by which name the species has been more recently defined. As we have not hitherto found any teeth of the macrota series from any of our beds, but only those of the compressa type, we think it better for the present to retain the latter name for our representatives.

Generally distributed through Europe in the Eocene and Miocene, and in the Eocene of North America.

Waipara and Oamaru formations of New Zealand Upper Cretaceous and Oligocene respectively.

Lamna bronni, Agassiz.

Lamna (Odontaspis) bronni, Agassiz, 1843. Poiss. Foss., vol. iii., p. 297, pl. 37a, figs. 8-10.

Odontaspis bronni, Ag., A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. i., p. 360.

Locality and Horizon.—Waurn Ponds, near Geelong (Pritchard Coll.).—Jan Jukian.

Observations.—Our specimen agrees exactly with Agassiz's original figure of this species, and, failing a complete series, we are unable to refer this to any other species.

The European representatives are only found in the Upper Cretaceous of Holland and Belgium (Maastricht, Ciply, and Hainaut).

Genus, *Oxyrhina*, Agassiz.

Oxyrhina hastalis, Agassiz. (Pl. I., Figs. 12-14).

Oxyrhina hastalis, Agassiz, 1843. Poiss. Foss., vol. iii., p. 277, pl. 34, figs. 3-13, 15-17.

Oxyrhina xiphodon, Agassiz, 1843. Ibid., p. 278, pl. 33, figs. 11-17.

Oxyrhina trigonodon, Agassiz, 1843. Ibid., p. 279, pl. 37, figs. 17-18.

Oxyrhina plicatilis, Agassiz, 1843. Ibid., p. 279, pl. 37, figs. 14-15.

Oxyhrina acuminata, Davis, 1888. Trans. R. Dublin Soc., ser. 2, vol. iv., p. 29, pl. v., figs. 21a-c.

Oxyrhina hastalis, Ag., A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. i., p. 385.

Locality and Horizon.—Lower Beds of Muddy Creek, Western Victoria (Pritchard Coll.); Leigh River at Shelford (Nat. Mus. Coll.); Mitchell River, near Bairnsdale (Nat. Mus. Coll., presented by A. W. Howitt); Balcombe's Bay (Pritchard Coll.).—Balcombian.

Beaumaris, Port Phillip (Nat. Mus. Coll., collected by W. Kershaw, presented by C. D. Aplin, J. F. Bailey, and C. French, jr.; also Dixon Coll. and Pritchard Coll.).

Grange Burn (Nat. Mus. Coll., purchased from R. Lindsay, and presented by G. Robinson; also Spry Coll. and Pritchard Coll.).

Observations.—This is the commonest of our Australian sharks' teeth, and as a consequence we are enabled to obtain a

good idea of the variation in the teeth from different parts of the jaw. In common with previous authors we have included several of Agassiz's species which were evidently given to designate teeth from different parts of the same jaw; the more erect and typical hastalis representing the large anterior teeth, xiphodon those of an intermediate position, plicatilis those of a lateral position, and smaller oblique forms representing the postero-laterals.

In America this species is Eocene, whilst in Europe it is generally Miocene, but extends also into the Pliocene, some of which are evidently derived from older beds.

This species was recorded for Victoria by the late Sir F. McCoy under the name of O. trigonodon in 1866 (15, p. 17).

Oxyrhina desori, Agassiz.

Oxyrhina desorii, Agassiz, 1843. Poiss. Foss., vol. iii., p. 202, pl. 37, figs. 8-13.

Oxyrhina leptodon, Agassiz, 1843. Ibid., p. 282, pl. 37, figs. 3-5.

Oxyrhina grandis, Davis, 1888. Trans. Roy. Dublin Soc., ser. 2, vol. iv., p. 30, pl. 5, figs. 15, 16.

Oxyrhina desorii, Ag., A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. i., p. 382.

Oxyrhina desorii, Ag., L. Seguenza, 1900. Boll. Soc. Geol. Ital., p. 482, pl. 5, figs. 1-12.

Locality and Horizon.—Waurn Ponds, near Geelong (Nat. Mus. Coll., purchased from J. F. Bailey, and from Mines Department [4766]; also J. F. Mulder Coll. and Pritchard Coll.).—Jan Jukian.

Birregurra (J. F. Mulder Coll.).—Barwonian.

Beaumaris, Port Phillip (Dixon Coll.; Pritchard Coll.); Grange Burn (Spry Coll.).—Kalimnan.

Observations.—The figures given by Davis represent the strong anterior teeth, and we also have the more slender and more oblique laterals.

This species is Upper Eocene in North America, and Upper Eocene, Miocene, and Pliocene in Europe. In New Zealand it occurs in the Waipara and Oamaru formations, Upper Cretaceous and Oligocene respectively.

Oxyrhina retroflexa, Agassiz.

Oxyrhina retroflexa, Agassiz, 1843. Poiss, Foss., vol. iii., p. 281, pl. 33, f. 10.

Oxyrhina crassa, Agassiz, 1843. Poiss. Foss., vol. iii., p. 283, pl. 37, fig. 16.

Oxyrhina vonhaastii, Davis, 1888. Trans. Roy. Dublin Soc., ser. 2, vol. iv., p. 26, pl. 4, figs. 1-3.

Oxyrhina crassa, Agassiz., A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. i., p. 389.

Locality and Horizon.—Three miles west of mouth of Gellibrand River (Geol. Surv. Vic., A.W. 9, Nat. Mus. Coll.).—Balcombian. Nine miles west of Casterton (Mines Department 3493 Nat. Mus. Coll.).—Barwonian.

Beaumaris, Port Phillip (Nat. Mus. Coll., purchased from J. F. Bailey, collected by W. Kershaw, presented by C. D. Aplin; also Pritchard Coll.). Grange Burn (Nat. Mus. Coll., presented by G. Robinson and A. A. Kelley, and purchased from R. Lindsay; also Spry Coll. and Pritchard Coll.).—Kalimnan.

Observations.—The series before us shows more perfect gradation than those figured by Davis as O. vonhaastii; the anterior teeth are fairly well represented by Agassiz's figure of O. crassa, whilst the short recurved form is undoubtedly his O. retroflexa. The relative abundance and variation in this form affords us a parallel example in dentition with O. hastalis. O. retroflexa has been included in the synonymy of O. hastalis by A. S. Woodward in his British Museum Catalogue, but, as our series is large and representative, we have been compelled to regard it as a distinct type.

This species in Europe is recorded from the Eocene, Miocene and Pliocene, and from the Eocene of North America.

The New Zealand specimens are from the Oamaru formation, Oligocène.

Oxyrhina eocaena, A. S. Woodward. sp.

Carcharias (Scoliodon) eocaenus, A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. i., p. 436.

Oxyrhina eocaena, A. S. Woodward, 1899. Proc. Geol. Assoc., vol. xvi., p. 11, pl. i., figs. 25, 26.

Locality and Horizon.—Beaumaris, Port Phillip (Dixon Coll.; Pritchard Coll.). Grange Burn (Nat. Mus. Coll., presented by A. A. Kelley, and purchased from R. Lindsay; also Pritchard Coll.).

Observations.—We have examined a fair number of specimens, which agree closely with the diagnosis and figures given by A. S. Woodward, but some of our examples are about twice the height of the type specimens. The original specimens came from the London clay, Highgate.

Oxyrhina minuta, Agassiz.

Oxyrhina minuta, Agassiz, 1843. Poiss. Foss., vol. iii., p. 285, pl. 36, figs. 39-47.

Oxyrhina fastigiata, Davis, 1888. Trans. Roy. Dublin Soc., ser. 2, vol. iv., p. 30, pl. 6, figs. 1-3.

Locality and Horizon.—Waurn Ponds, near Geelong (J. F. Mulder Coll.; Pritchard Coll.).—Jan Jukian.

East of Gellibrand River (Geo. Surv. Vic. A.W., 7, Nat. Mus. Coll.). Lower Beds of Muddy Creek (Pritchard Coll.).—Balcombian.

Belmont (J. F. Mulder Coll.).—Barwonian.

Grange Burn (Spry Coll.; Pritchard Coll.).—Kalimnan.

Observations.—To this species we have referred numerous slender minute teeth which do not appear to belong to any other series, and are exactly comparable with the figures of both the above-mentioned forms. O. minuta has been recorded from the Lower Miocene of Osnabruck, Prussia, and Piedmont, Naples, and Sicily. It occurs in N. Zealand in the Oamaru formation (Oligocene).

Genus *Carcharodon*, Müller and Henle.

Carcharodon auriculatus, Blainville, sp.

Squalus auriculatus, de Blainville, 1818. Nouv. Dict. d'Hist. Nat., vol. xxvii., p. 384.

Carcharodon auriculatus, Agassiz, 1843. Poiss. Foss., vol. iii., p. 254, pl. 28, figs. 17-19.

Carcharodon angustidens, Agassiz, 1843. Ibid., p. 255, pl. [illegible] 20 . pl. 30, f. 3.

Carcharodon angustidens, Agassiz, McCoy, 1875. Prod. Pal. Vic., dec. ii., p. 8, pl. 11, f. 2, 3.

Carcharodon angustidens, Agassiz, Davis, 1888. Trans. Roy. Dublin Soc., ser. 2, vol. iv., p. 9, pl. i., figs. 4-6, and pl. 6, f. 22.

Carcharodon auriculatus, Blainville sp., A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., part i., p. 411.

Locality and Horizon.—Waurn Ponds (Nat. Mus. Coll., purchased J. F. Bailey; Pritchard Coll.). Table Cape (Nat. Mus. Atkinson Coll.). Spring Creek or Bird Rock Bluff, near Geelong. (Nat. Mus. Coll., presented by A. E. Butler). West of Rocky Point, Spring Creek section (Hall Coll.).—Jan Jukian.

Nine miles W. of Casterton (Nat. Mus. Coll. from Mines Department, 3493). Casterton (Nat. Mus. Coll., presented by Miss Wilson).—Barwonian.

Grange Burn (Spry Coll.).—Kalimnan, probably derived from Balcombian.

Observations.—Specimens in our collection show the same range of variation as has already been indicated by the forms figured as Carcharodon auriculatus, angustidens, heterodon, toliapicus, etc.

This species appears essentially to belong to the Barwonian series, as our knowledge of its existence in the Kalimnan is restricted to one worn specimen.

Middle and Upper Eocene of Europe and North America, and from the Miocene and Pliocene of Europe. This species is also recorded from the Oamaru formation (Oligocene) of New Zealand.

Carcharodon megalodon, Agassiz.

Carcharodon megalodon, Agassiz, 1843. Poiss. Foss., vol. iii., p. 247, pl. 19.

Carcharodon megalodon, Agassiz, McCoy, 1875. Prod. Pal. Vic., dec. ii., p. 9, pl. ii., f. 4 and 4a-c.

Carcharodon megalodon, Agassiz, Davis, 1888. Trans. Roy. Dublin Soc., ser. 2, vol. iv., p. 12, pl. 2, figs. 1-3.

Carcharodon megalodon, Agassiz, A. S. Woodward, 1889. Cat. Foss. Fishes, Brit. Mus. Nat. Hist., pt. i., p. 415.

Locality and Horizon.—Waurn Ponds (Pritchard Coll.); Spring Creek or Bird Rock Bluff (Nat. Mus. Coll. Geo. Surv. Vic.).—Jan. Jukian.

Grange Burn Lower limestones (Pritchard Coll.); ?Muddy Creek (Nat. Mus. Coll.); Muddy Creek (Sweet Coll.); Clays of Native Hut Creek, near Inverleigh (Pritchard Coll.).—Balcombian.

Grange Burn, near Hamilton (Nat. Mus. Coll., purchased R. Lindsay, much worn); Beaumaris, Port Phillip, conglomerate bed, probably derived (Pritchard Coll.).—Kalimnan.

Observations.—The specimen of this species figured by McCoy is about the smallest of the specimens known from the Australian Tertiary beds, but it is in a very good state of preservation. It may be interesting to note the measurements of a few of the largest specimens. From Muddy Creek, height 11 cm., breadth 10 cm.; from Grange Burn, height 12 cm. nearly, breadth 11 cm.; from Native Hut Creep, height 12 cm., breadth 10.5 cm. (approximate, owing to fracture).

Eocene of North America; Miocene and Pliocene of Europe; Miocene of Burma; Tertiary of Java; Oamaru formation (Oligocene) New Zealand.

There is also a record in the British Museum Catalogue of a plaster cast of a large tooth from the "Upper Tertiary," Lake Bonny, South Australia, which was presented to the Museum by Sir Samuel Davenport (op. cit., p. 420.).

Carcharodon robustus, Davis.

Carcharodon robustus, Davis, 1888. Trans. Roy. Dublin Soc., ser. 2, vol. iv., p. 13. pl. 1, f. 7.

Locality and Horizon.—Waurn Ponds (Pritchard Coll.).—Jan. Jukian. Lower Beds of Muddy Creek below Mason's (Pritchard Coll.).—Balcombian.

Observations.—This species has been included in the synonymy of C. megalodon (30. p. 417) by A. S. Woodward, but the forms in our collection are so distinct a type of tooth that it necessitates the retention of Davis' species as distinct from C. megalodon. Davis records his species from the Oamaru formation (Oligocene), New Zealand.

TABLE OF DISTRIBUTION OF TERTIARY SPECIES OF AUSTRALIAN SHARKS. *(Continued).*

Subjects.	Localities.	Relative Abundance.	Stratigraphical Horizon.
11. Odontaspis incurva, Davis, sp.	Grange Burn, Beaumaris	Occasional (worn)	Kalimnan
	Warranooke	Rare	Barwonian
	Waurn Ponds	Occasional	Jan Jukian
12. Odontaspis cuspidata, Agassiz, sp.	Grange Burn, Beaumaris	Rare	Kalimnan
	Gellibrand River	Rare	Balcombian
	Cape Otway	Rare	Jan Jukian
13. Odontaspis attenuata, Davis, sp.	Beaumaris	Rare	Kalimnan
	Belmont	Rare	Barwonian
	Lower Aldinga, Waurn Ponds	Rare	Jan Jukian
14. Lamna crassidens, Agassiz	Muddy Creek, Balcombe's Bay	Occasional	Balcombian
	Spring Creek, Waurn Ponds	Occasional	Jan Jukian
15. Lamna apiculata, Agassiz, sp.	Grange Burn, Beaumaris	Occasional	Kalimnan
	Casterton	Rare	Barwonian
	Muddy Creek, Balcombe's Bay, Gellibrand River	Occasional	Balcombian
	Waurn Ponds	Common	Jan Jukian
16. Lamna compressa, Agassiz	Grange Burn, Beaumaris	Rare	Kalimnan
	Warranooke	Rare	Barwonian
	Table Cape, Tas.	Rare	Jan Jukian
17. Lamna bronni, Agassiz	Waurn Ponds	Rare	Jan Jukian
18. Oxyrhina hastalis Agassiz	Grange Burn, Beaumaris	Abundant	Kalimnan
	Muddy Creek, Shelford, Balcombe's Bay, Mitchell River	Occasional	Balcombian

TABLE OF DISTRIBUTION OF TERTIARY SPECIES OF AUSTRALIAN SHARKS. *(Continued).*

Subjects.	Localities.	Relative Abundance.	Stratigraphical Horizon.
19. Oxyrhina desori, Agassiz	Grange Burn, Beaumaris	Occasional	Kalimnan
	Birregurra	Rare	Barwonian
	Waurn Ponds	Common	Jan Jukian
20. Oxyrhina retroflexa, Agassiz	Grange Burn, Beaumaris	Common	Kalimnan
	Casterton	Rare	Barwonian
	Gellibrand River	Rare	Balcombian
21. Oxyrhina eocaena, Woodward, sp.	Grange Burn, Beaumaris	Rare	Kalimnan
22. Oxyrhina minuta, Agassiz	Grange Burn	Common	Kalimnan
	Belmont	Rare	Barwonian
	Gellibrand River, Muddy Creek	Occasional	Balcombian
	Waurn Ponds	Occasional	Jan Jukian
23. Carcharodon auriculatus, Blainville, sp.	Grange Burn	Rare	Kalimnan
	Casterton	Occasional	Barwonian
	Waurn Ponds, Spring Creek, Table Cape, Tas.	Occasional	Jan Jukian
24. Carcharodon megalodon, Agassiz	Grange Burn, Beaumaris	Rare	Kalimnan
	Muddy Creek, Native Hut Creek, Grange Burn Lower Limestones	Rare	Balcombian
	Waurn Ponds, Spring Creek	Rare	Jan Jukian
25. Carcharodon robustus, Davis	Muddy Creek	Rare	Balcombian
	Waurn Ponds	Rare	Jan Jukian

V. DISTRIBUTION OF TERTIARY SHARKS OUTSIDE AUSTRALIA.

Species.	Geographical Distribution.	Geological Range.
Galeocerdo davisi, nom. mut. (= Notidanus marginalis, Davis, pars.)	New Zealand	Upper Cretaceous and Oligocene
Galeocerdo latidens, Ag.	Europe, Egypt, and N. America	Middle Eocene
Galeocerdo aduncus, Ag.	Europe and N. America	Eocene to Pliocene
Carcharias (Prionodon) acutus, Ag.	Westphalia	Upper Cretaceous
Sphyrna prisca, Ag.	Europe and N. America	Eocene and Miocene
Odontaspis contortidens, Ag.	Europe and N. America	Eocene to Pliocene
Odontaspis incurva, Davis, sp.	New Zealand	Upper Cretaceous and Oligocene
Odontaspis cuspidata, Ag., sp.	Europe, N. America, and New Zealand	Upper Cretaceous to Miocene
Odontaspis attenuata, Davis, sp.	New Zealand	Oligocene
Lamna crassidens, Ag.	Europe and N. America	Eocene and Miocene
Lamna apiculata, Ag., sp.	France, New Zealand	Upper Cretaceous to Oligocene
Lamna compressa, Ag.	Europe, N. America, and New Zealand	Upper Cretaceous to Miocene
Lamna bronni, Ag.	Netherlands	Upper Cretaceous
Oxyrhina hastalis, Ag.	N. America, Europe, Canary and Cape de Verde Isles	Eocene to Pliocene
Oxyrhina desori, Ag.	Europe, N. America	Upper Eocene to Pliocene
Oxyrhina retroflexa, Ag.	Europe, N. America, New Zealand	Eocene to Pliocene
Oxyrhina eocaena, A.S.W., sp.	England	Lower Eocene
Oxyrhina minuta, Ag.	Germany, Italy	Lower Miocene
Carcharodon auriculatus, Blainville, sp.	Europe, N. America, New Zealand	Middle Eocene to Pliocene
Carcharodon megalodon, Ag.	N. America, Europe, Burma, Java, and New Zealand	Eocene to Pliocene
Carcharodon robustus, Davis	**New Zealand**	**Oligocene**

VI.—Comparative Table of the Selachian Remains from the Northern Hemisphere and Australia.

Species.	Geol. Range in N. Hemisphere.	Geol. Range in Australia.
Carcharias acutus, Ag	Upper Cretaceous	Barwonian (Jan Jukian).
Sphyrna prisca, Ag.	Eocene and Miocene	Barwonian (Balcombian).
Odontaspis contortidens, Ag.	Eocene—Pliocene	Barwonian (Jan Jukian and Balcombian), Kalimnan.*
O. cuspidata, Ag., sp.	Eocene—Miocene	Barwonian (Jan Jukian and Balcombian), Kalimnan.*
Lamna crassidens, Ag.	Eocene and Miocene	Barwonian (Jan Jukian and Balcombian).
L. apiculata, Ag., sp.	Tertiary	Barwonian (Jan Jukian and Balcombian), Kalimnan.*
L. compressa, Ag.	Eocene and Miocene	Barwonian (Jan Jukian).
L. bronni, Ag.	Upper Cretaceous	Barwonian (Jan Jukian).
Oxyrhina hastalis, Ag.	Eocene—Pliocene	Barwonian (Balcombian), Kalimnan.*
O. desori, Ag.	Upper Eocene—Pliocene	Barwonian (Jan Jukian), Kalimnan.
O. retroflexa, Ag.	Eocene—Pliocene	Barwonian (Balcombian), Kalimnan.
O. eocaena, A. S. Woodward, sp.	Lower Eocene	Kalimnan.*
O. minuta, Ag.	Lower Miocene	Barwonian (Jan Jukian), Kalimnan.
Carcharodon auriculatus, Blainville, sp.	Mid. Eocene—Pliocene	Barwonian (Jan Jukian), Kalimnan.*
C. megalodon, Ag.	Eocene—Pliocene	Barwonian Balcombian), Kalimnan.*

* Probably derived.

V.—Distribution of Tertiary Sharks Outside Australia.

Species.	Geographical Distribution.	Geological Range.
Galeocerdo davisi, nom. mut. (=Notidanus marginalis, Davis, pars.)	New Zealand	Upper Cretaceous and Oligocene
Galeocerdo latidens, Ag.	Europe, Egypt, and N. America	Middle Eocene
Galeocerdo aduncus, Ag.	Europe and N. America	Eocene to Pliocene
Carcharias (Prionodon) acutus, Ag.	Westphalia	Upper Cretaceous
Sphyrna prisca, Ag.	Europe and N. America	Eocene and Miocene
Odontaspis contortidens, Ag.	Europe and N. America	Eocene to Pliocene
Odontaspis incurva, Davis, sp.	New Zealand	Upper Cretaceous and Oligocene
Odontaspis cuspidata, Ag., sp.	Europe, N. America, and New Zealand	Upper Cretaceous to Miocene
Odontaspis attenuata, Davis, sp.	New Zealand	Oligocene
Lamna crassidens, Ag.	Europe and N. America	Eocene and Miocene
Lamna apiculata, Ag., sp.	France, New Zealand	Upper Cretaceous to Oligocene
Lamna compressa, Ag.	Europe, N. America, and New Zealand	Upper Cretaceous to Miocene
Lamna bronni, Ag.	Netherlands	Upper Cretaceous
Oxyrhina hastalis, Ag.	N. America, Europe, Canary and Cape de Verde Isles	Eocene to Pliocene
Oxyrhina desori, Ag.	Europe, N. America	Upper Eocene to Pliocene
Oxyrhina retroflexa, Ag.	Europe, N. America, New Zealand	Eocene to Pliocene
Oxyrhina eocaena, A.S.W., sp.	England	Lower Eocene
Oxyrhina minuta, Ag.	Germany, Italy	Lower Miocene
Carcharodon auriculatus, Blainville, sp.	Europe, N. America, New Zealand	Middle Eocene to Pliocene
Carcharodon megalodon, Ag.	N. America, Europe, Burma, Java, and New Zealand	Eocene to Pliocene
Carcharodon robustus, Davis	New Zealand	Oligocene

VI.—Comparative Table of the Selachian Remains from the Northern Hemisphere and Australia.

Species.	Geol. Range in N. Hemisphere.	Geol. Range in Australia.
Carcharias acutus, Ag	Upper Cretaceous	Barwonian (Jan Jukian).
Sphyrna prisca, Ag.	Eocene and Miocene	Barwonian (Balcombian).
Odontaspis contortidens, Ag.	Eocene—Pliocene	Barwonian (Jan Jukian and Balcombian), Kalimnan.*
O. cuspidata, Ag., sp.	Eocene—Miocene	Barwonian (Jan Jukian and Balcombian), Kalimnan.*
Lamna crassidens, Ag.	Eocene and Miocene	Barwonian (Jan Jukian and Balcombian).
L. apiculata, Ag., sp.	Tertiary	Barwonian (Jan Jukian and Balcombian), Kalimnan.*
L. compressa, Ag.	Eocene and Miocene	Barwonian (Jan Jukian).
L. bronni, Ag.	Upper Cretaceous	Barwonian (Jan Jukian).
Oxyrhina hastalis, Ag.	Eocene—Pliocene	Barwonian (Balcombian), Kalimnan.*
O. desori, Ag.	Upper Eocene—Pliocene	Barwonian (Jan Jukian), Kalimnan.
O. retroflexa, Ag.	Eocene—Pliocene	Barwonian (Balcombian), Kalimnan.
O. eocaena, A. S. Woodward, sp.	Lower Eocene	Kalimnan.*
O. minuta, Ag.	Lower Miocene	Barwonian (Jan Jukian), Kalimnan.
Carcharodon auriculatus, Blainville, sp.	Mid. Eocene—Pliocene	Barwonian (Jan Jukian), Kalimnan.*
C. megalodon, Ag.	Eocene—Pliocene	Barwonian Balcombian), Kalimnan.*

* Probably derived.

VII.—Summary of Conclusions.

From the foregoing examination of our Tertiary fish remains the following principal points may be summarized:—

The genus Asteracanthus previously recorded by Tate from the Balcombian and Kalimnan, under the generic name of Strophodus, undoubtedly belongs to the former genus, evidence being rendered by the microscopic structure of the teeth. This extends beyond question the range of this hitherto Jurassic and Upper Cretaceous fish into the Tertiary seas round Southern Australia.

With regard to the identified species, two Upper Cretaceous species occur in our beds of Jan Jukian age, viz.—

Carcharias acutus and Lamna bronni.

One species—Oxyrhina minuta—is apparently a comparatively restricted Miocene form in the Northern Hemisphere, and occurs here in the Jan Jukian, Balcombian, and Kalimnan. Ten species have a comparatively wide geological range in the tertiaries, both in the Southern and Northern Hemispheres, namely:—S. prisca, O. contortidens, O. cuspidata, L. crassidens, L. compressa, Ox. hastalis, Ox. desori, Ox. retroflexa, C. auriculatus, and C. megalodon.

These data do not furnish any very clear evidence of our tertiary succession and relative age of the beds, since the fauna has a general tertiary aspect, but the occurrence of the few Mesozoic forms gives an aspect of antiquity to the older portion of our tertiary strata.

With regard to the occurrence of certain species found both in New Zealand and Australian strata, we gather some interesting information, which points to some affinity with the Cretaceo-Tertiary Group of the former area.

	New Zealand.		Australia.			
	1.	2.	3.	4.	5.	6.
Name of Species.	Upper Cretaceous.	Oligocene.	Jan Jukian.	Balcombian.	Barwonian.	Kalimnan.
Galeocerdo davisi	1	2		4	5	
Odontaspis incurva	1	2	3		5	
Odontaspis cuspidata	1	2	3	4	5	6
Odontaspis attenuata	1	2	3		5	6
Lamna apiculata	1	2	3	4	5	6
Lamna compressa	1	2	3		5	6
Oxyrhina desori	1	2	3		5	6

Oxyrhina retroflexa	1	2		4	5	6
Oxyrhina minuta	1	2	3	4	5	6
Carcharodon auriculatus	1	2	3	4	5	6
Carcharodon megalodon	1	2	3	4	5	6
Carcharodon robustus	1	2		4	5	

From the state of preservation of the specimens in our beds, we have no hesitation in stating that we think the majority of the occurrences in the Kalimnan beds are due to their having been derived from the older Barwonian beds. This we think is somewhat analagous to the fact of so many Pliocene specimens being of a derived character in the Northern Hemisphere, and, where no indication of the state of preservation is given, the results of an inquiry into the distribution of species may be somewhat misleading.

The local terms, Kalimnan, Balcombian, Jan Jukian, and Barwonian, have been used by us owing to the very considerable confusion and difference of opinion surrounding the use of the ordinary terms such as Miocene, Oligocene, Eocene, and to the fact that as yet there is no absolute certainty on the stratigraphical succession of our beds.

As far as the evidence points up to the present, the older series has been termed Barwonian[1] with its two sub-divisions, Balcombian and Jan Jukian, of which the latter has been indicated as the older.[2] To this series various ages have been assigned, such as Eocene, Oligocene, and Miocene, for different portions of the same series.

Then for the series distinctly unconformable to the Barwonian and distinctly separable by its molluscan fauna the name of Kalimnan has been given[3]; and this series has been variously referred to as Oligocene, Miocene, and Pliocene.

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EXPLANATION OF PLATES.

PLATE XI.

[The numbers in square brackets refer to registered specimens in the National Museum, Melbourne.]

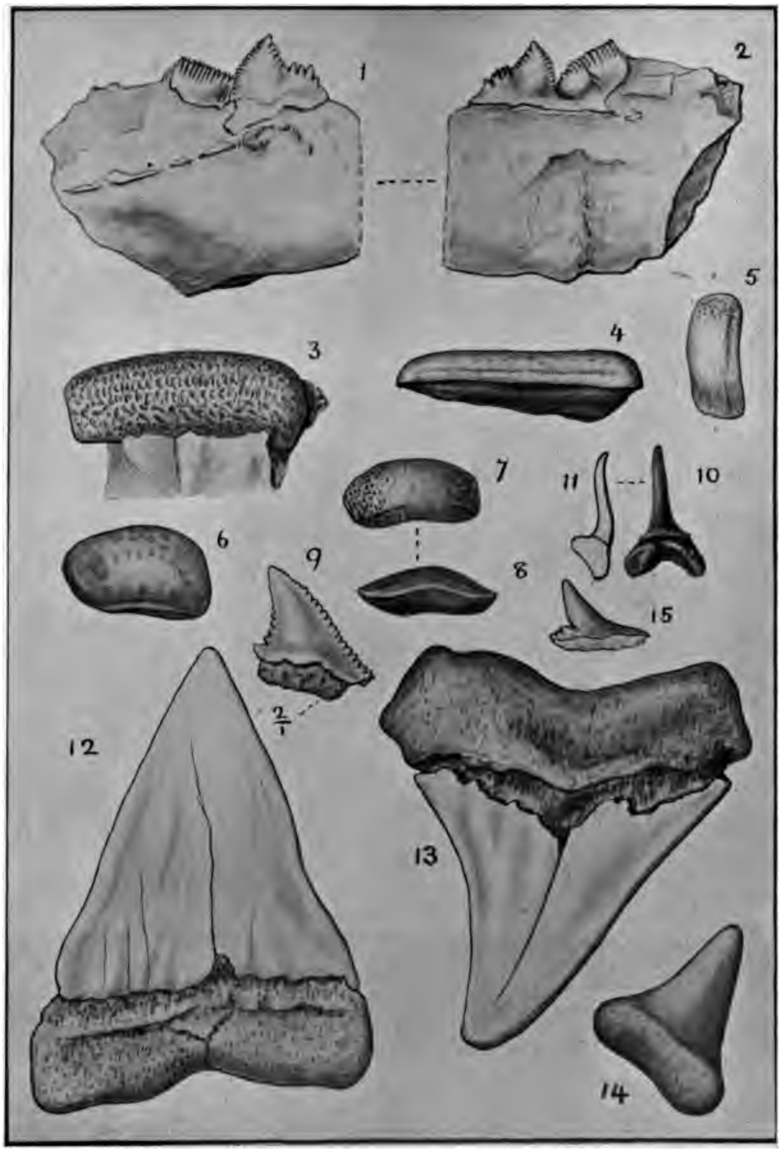
Fig. 1. *Notidanus jenningsi*, sp. nov. Part of (?) left lower jaw, outer side; from Beaumaris. Natural size. [5368].

Fig. 2. *Notidanus jenningsi*, sp. nov. Inner side of jaw; from Beaumaris. Natural size. [5368].

Fig. 3. *Asteracanthus eocaenicus*, Tate sp. Upper surface of tooth; from Moorabool River. Natural size. [5378].

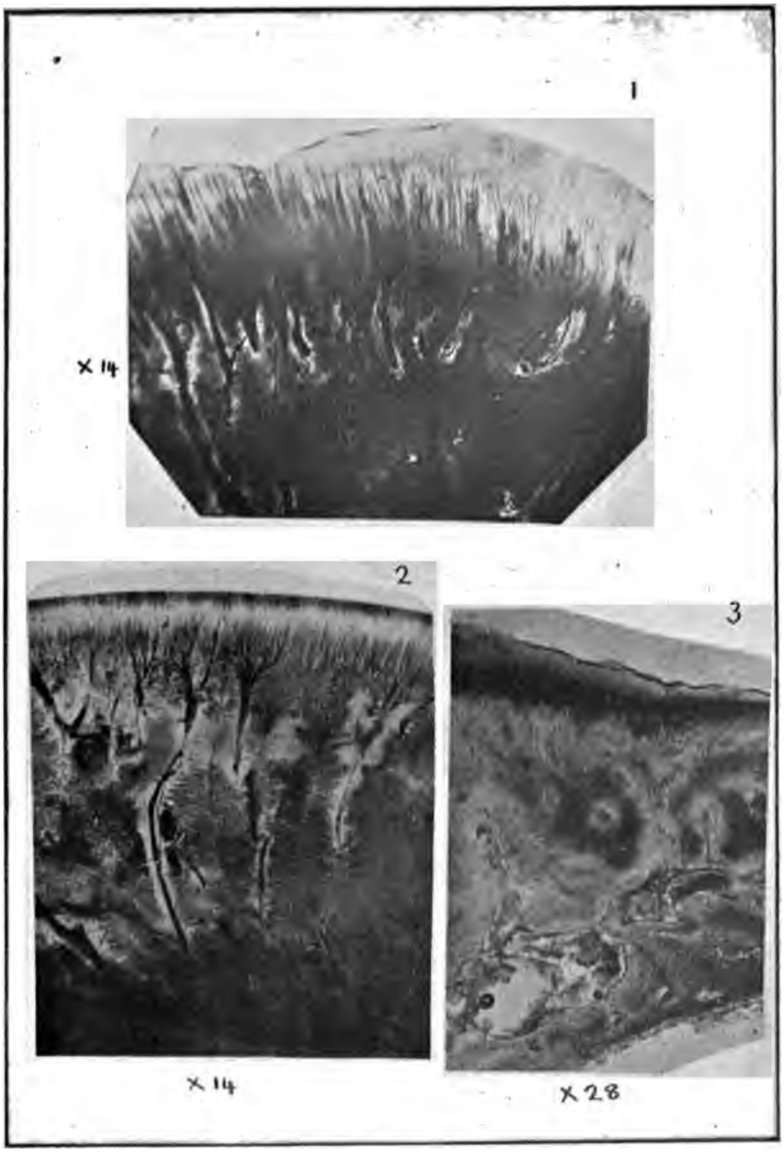
Fig. 4. *Asteracanthus eocaenicus*, Tate sp. Lateral aspect of tooth; from Moorabool River. Natural size. [5379].

Fig. 5. *Cestracion cainozoicus*, sp. nov. Upper surface of lateral tooth from middle of series; from Beaumaris. Natural size. [5372].



F. C. DELT.

Teeth of Australian Tertiary Sharks.



F. C. PHOTO.

Vertical Sections of Teeth of Asteracanthus and Cestracion.

Fig. 6. *Cestracion cainozoicus*, sp. nov. Upper surface of lateral tooth from back of series; from Beaumaris. Natural size. [5374].

Fig. 7. *Cestracion cainozoicus*, sp. nov. Upper surface of lateral tooth from front of series; from Beaumaris. Natural size. [5369].

Fig. 8. *Cestracion cainozoicus*, sp. nov. Edge view of lateral tooth; from Beaumaris. Natural size. [5369].

Fig. 9. *Sphyrna prisca*, Ag. Tooth; from Fyansford. × 2. [5435].

Fig. 10. *Odontaspis attenuata*, Davis, sp. Inner surface of tooth; from Beaumaris. Natural size. [5377].

Fig. 11. *Odontaspis attenuata*, Davis, sp. Edge view of tooth; from Beaumaris. Natural size. [5434].

Fig. 12. *Oxyrhina hastalis*, Ag. Outer surface of anterior tooth; from Beaumaris. Natural size. [5434].

Fig. 13. *Oxyrhina hastalis*, Ag. Outer surface of tooth from upper jaw; from Beaumaris. Natural size. [5426].

Fig. 14. *Acanthias geelongensis*, sp. nov. Outer surface of tooth. × 2. [5386].

Plate XII.

Fig. 1. Vertical section of tooth of *Asteracanthus eocaenicus*, Tate sp. Osteodentine showing a regular series of vertical pulp-canals, and the fasciculated groups of canaliculi emanating from them. × 14.

Fig. 2. Vertical section of lateral tooth of *Cestracion cainozoicus*, sp. nov. Showing the irregular character of the pulp-canals, and concentration of the canaliculi beneath structureless layer near the surface. × 14.

Fig. 3. Vertical section of lateral tooth of young *Cestracion philippi* from Port Phillip, recent. Showing irregular pulp-canals and lacunae; also concentration of canaliculi under structureless layer near the surface. × 28.

Fig. 4. *Oxyrhina hastalis*, Ag. Outer surface of posterior tooth; from Beaumaris. Natural size. [5424].

ART. IX.—*New or Little-known Victorian Fossils in the National Museum, Melbourne.*

PART IV.—SOME SILURIAN OSTRACODA AND PHYLLOCARIDA.

BY FREDERICK CHAPMAN, A.L.S., &c.,

National Museum.

(With Plates XIII.-XVII).

[Read 14th July, 1904].

INTRODUCTORY REMARKS.

The whole of these Ostracoda now first recorded for Victoria, or described as new, have been obtained from the soft, friable or granular portions of the pale greyish limestone of Cave Hill, Lilydale. For some of this ostracod-bearing material the Museum is indebted to Mr. G. B. Pritchard, whilst other samples were collected by myself from the same locality. The specimen of Cyprosina was collected at Lilydale by the Rev. A. W. Cresswell, M.A.

Of the 26 species of Ostracoda, one-half of the number are forms of Primitia, a genus which, ranging from the Cambrian to the Carboniferous formations, seems to have attained its maximum development in Silurian times. The other genera, with the exception of Cyprosina, a Middle Devonian form in England, are, generally speaking, of Ordovician and Silurian ages; whilst others are apparently referable to living genera, so far as we are able to judge from the characters of the carapace alone.

With regard to the 17 already known species, now recorded for the first time from Australia, 4 are Ordovician (generally Upper) types elsewhere, 11 are from the Silurian (generally Wenlockian), whilst 1 is of Lower Devonian age (in Canada), and 1 belongs to the Lower Carboniferous (England).

The Phyllocarida also afford some very interesting data for distributional comparison. The genera Ceratiocaris and Aptychopsis are both characteristic of Silurian strata in Europe and North America, the former genus being found also in the Ordovician. They are both apparently newly recorded for Australia. The genus Dithyrocaris is found in the Devonian and Carboniferous of Scotland, and in the Devonian of Germany. In N. America it seems to be confined to the Carboniferous (Illinois and Pennsylvania).

DESCRIPTION OF SPECIES.

OSTRACODA.

Family *Leperditiidae.*

Genus *Isochilina,* Jones.

Isochilina labrosa, Jones. (Pl. XVI., Figs. 3a, b).

Isochilina labrosa, Jones, 1889. Ann. Mag. Nat. His., ser. 6, vol. iii., p. 383, pl. xvii,, fig. 11, ii., and woodcuts 3 and 4, p. 384.

Observations.—The Victorian specimen closely resembles the type specimen from the greenish-grey calcareous shale of Cape Bon-Ami, Canada, figured by Rupert Jones. If in anything, our specimen differs in being less steep and more evenly rounded towards the central border. The Canadian specimens occurred in the Lower Helderbergian series, equivalent to the Gedinnian of Western Europe (Lower Devonian).

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Genus *Aparchites,* Jones.

Aparchites subovatus, Jones. (Plate XIV., Figs. 10a-c).

Aparchites subovatus, Jones, 1893. Quart. Journ. Geol. Soc., vol. lxix., p. 292, pl. xii., figs. 7, 8 a-c.

Observations.—This species was figured by Professor Jones from examples obtained from the Upper Ordovician (Staurocephalus Limestone series) of the Lake District, N. of England. Both smooth and punctate forms are nearly isomorphous with Primitia minuta, Eichwald sp. Our specimen is intermediate in character between the typical smooth forms, which it resembles in outline, and the punctate variety, which it also simulates in surface ornament. The present examples seem to emphasise the fact of the variability of this species, and to render the separation of the variety as a distinct species from the typical form, for the present, unnecessary.[1]

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Genus *Primitia*, Jones and Holl.

Primitia trigonalis, Jones and Holl. (Plate XV., Figs. 8A-C).

Primitia trigonalis, Jones and Holl, 1865. Ann. Mag. Nat. Hist., ser. 3, vol., xvi., p. 421, pl. xiii., figs. 4 a, b.

Observations.—The English specimens came from the Wenlock Limestone of Malvern. I have referred the example before me to the above species, with at first some hesitation on account of the somewhat elongate carapace, but taking into consideration the general thickness of the carapace and the strong compression of the valve edges, it may provisionally be referred to P. trigonalis. It differs from the following species, P. subtrigonalis, sp. nov., in its greater relative thickness and compressed margins, and also in the greater angularity in its lateral outline. Our example of the above form carries a series of minute denticules on the posterior edge and on the antero-dorsal angle of the valves.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

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1 Prof. Jones remarks (*loc. cit.*) on the Lake District specimens as follows:—"Figs. 7, 8 appear to be varieties of one form; although possibly if we had better material to study they might be found to be quite distinct."

Primitia subtrigonalis, sp. nov. (Pl. XIII., Figs. 1a-c).

Description.—Carapace convex, margins blunt; lateral outline subtrigonal with evenly rounded dorsal angles; anterior end somewhat produced, posterior broadly rounded. Sub-central pit rather conspicuous and circular. Edge view elongate-ovate, slightly more compressed anteriorly. End view regularly ovate. Edges of valves thickened, especially the dorsal and ventral borders of the left, giving an appearance of overlapping. Surface of valves finely punctate.

Dimensions.—Length of carapace, .7 mm.; height, .5 mm.; thickness, .3 mm.

Affinities.—The above species seems to approach most nearly in outline P. trigonalis, Jones and Holl,[1] from the Wenlock Limestone, but it differs in the more elongate form of the carapace, the blunter edges of the valves and in having a well-marked sub-central depression.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Primitia punctata, Jones. (Pl. XIII., Figs. 2a-c).

Primitia punctata, Jones, 1887. Ann. Mag. Nat. Hist., ser. 5, vol. xix., p. 193, pl. vii., figs. 9 a, b.

Observations.—The long-oblong carapace with its strongly convex sides, the usually faint mid-dorsal sulcus and the punctate surfaces of the valves confirms the relationship of our examples with the above species.

P. punctata was originally described from the shales over the Wenlock Limestone of Shropshire, England, and I have since recorded it from the Silurian (Wenlockian) of Mulde, Gothland.[2]

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Primitia semicultrata, sp. nov. (Pl. XIII., Figs. 4a-c).

Description.—Carapace seen from the side, oblong and strongly convex. Dorsal edge straight, ventral nearly so, but slightly

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1 Ann. Mag. Nat. Hist., ser. 3, vol. xvi., 1865, p. 421, pl. xiii., figs. 4a, b.
2 Ann. Mag. Nat. Hist., ser. 7, vol. vii., 1901, p. 148.

concave in the centre; extremities of carapace compressed, the edges of the valves forming a flange-like border which, anteriorly, is somewhat produced and sloped gently away to the dorsal and ventral edges; whilst posteriorly the dorsal angle is evenly rounded, and the ventral rather irregularly so, making a wider angle with the ventral border. Edge view sub-triangular, broad posteriorly, and gradually sloping away towards the anterior end, with a depressed area, however, in the region of the dorsal sulcus; thickest in the middle of the posterior third. End view sub-elliptical, rather compressed ventrally, rounded dorsally. Surface of valves finely punctate; with a narrow but distinct median channel, at right angles to the dorsal edge, ending in a small pit-like depression near the centre of each valve.

Dimensions.—Length of carapace, .85 mm.; height, .3 mm.; thickness, 5 mm.

Observations.—The above species seems to present us with a somewhat exceptional type of Primitia in the striking character of the flange-like extremities. A comparison of the species which come nearest to this form leads one to see a probable ally in Primitia renulina, Jones and Holl,[1] from the Wenlock Limestone of Malvern, England. The latter species is, however, markedly distinct from ours in having a sub-oval valve, and a saddle-shaped depression close to the dorsal margin.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Primitia (?) matutina, Jones and Holl. (Pl. XIII., Figs. 5a, b).

Primitia ? matutina, Jones and Holl, 1865. Ann. Mag. Nat. Hist., ser. 3, vol. xvi., p. 5, pl. xiii., figs. 7 a, b.

Observations.—The above species, which was described from the Upper Ordovician (Upper Bala) of Shropshire, closely resembles our specimen, which unfortunately is imperfect, in its general features, both in outline and in the relative compression of the valves. The figured specimen of P. matutina referred to is a right valve, and may therefore be the more readily com-

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1 Ann. Mag. Nat. Hist., ser. 3, vol. xvi., 1865, p. 419, pl. xiii., figs. 5a, b.

pared with our specimen figured in the same aspect. The ventral border in the latter example is more strongly curved than that in P. matutina from Shropshire, and there is also a faint mid-dorsal pit which was not seen in the English specimen, although this feature is characteristic of Primitia. The dimensions given of the English specimen slightly exceed those of our form. In view of the slight differences referred to above, the specific determination is given with some reserve.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Primitia reticristata, Jones. (Pl. XIII., Figs. 7a-c).

Primitia reticristata, Jones, 1887. Sil. Ostrac. Gothland, p. 5.

P. reticristata, Jones, 1888. Ann. Mag. Nat. Hist., ser. 6, vol. i., p. 406, pl. xxii., figs. 15 a-c.

P. reticristata, Jones, Krause, 1891. Zeitschr, Deutsch. Geol. Gesellsch, p. 495, pl. xxx., figs. 8 a-d, 9 a-d.

Observations.—The previous occurrences for this neat and characteristic Primitia are Fröjel and Mulde, Gotland (Silurian), and also from the drifted Silurian blocks of N. Germany. Our specimens are typical, and they are not rare.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Primitia (cf.) **obsoleta**, Jones and Holl. (Pl. XIII., Figs. 8a-c).

Primitia obsoleta, Jones and Holl, 1865. Ann. Mag. Nat. Hist., ser. 3, vol. xvi., p. 423, pl. xiii., figs. 12 a-c.

Observations.—The present example agrees most nearly with the above species in the form of the carapace and the simple flanged border, which, however, in our specimen does not die away towards the anterior extremity as in Jones and Holl's specimen. The original specimen came from the Silurian drifted blocks of Scandinavian limestone, North Germany.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Primitia halli, sp. nov. (Pl. XIV., Figs. 2a-c).

Description.—Carapace elongate and sub-rhomboidal as seen from the side, with both the anterior and posterior angles, dorsal and ventral, rather sharply truncated; dorsal border straight, ventral slightly concave. Dorsal furrow sub-triangular. Dorsal margin having a narrow flange which is continued partly along the antero- and postero-dorsal margins. Edge view compressed ovate, thickest in the anterior third. Anterior end compressed, posterior compressed and somewhat bluntly rounded. End view sub-cordate. The right valve somewhat smaller than the left. Surface somewhat uneven or sparsely pitted.

Dimensions.—Length of compace, 1.08 mm.; height, .43 mm.; thickness, .35 mm.

Observations.—The above species is apparently distinct from any hitherto known forms of Primitia. The only species which is at all comparable with ours is P. furcata Jones and Holl[1], but this is much higher posteriorly, whilst anteriorly it tapers from the curved ventral to the dorsal margin, and the hinder portion of the carapace is considerably thicker and blunt-ended.

This species may very appropriately be associated with the name of Mr. T. S. Hall, M.A., with whom I had the pleasure of first visiting the Cave Hill quarry, and on which occasion we obtained material fairly rich in ostracoda.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Primitia elongata, Krause, *var.* **nuda**, Jones. (Pl. XIV., Figs. 3a-c).

Primitia elongata, Krause, var. nuda, Jones, 1893. Quart. Journ. Geol. Soc., vol. xlix., p. 298, pl. xiii., fig. 6.

Observations.—Our examples agree exactly with Prof. Jones' figure with the exception that the dorsal sulcus is represented by a well-defined depression. Both the type and the variety originally came from the Ordovician, of Scandinavia and Scotland respectively.

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1 Ann. Mag. Nat. Hist., ser. 5, vol xvii., 1886, p. 413, pl. xiv., figs. 15a, b.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Primitia paucipunctata, Jones and Holl. (Pl. XIV., Figs. 4a-c; Pl. XV., Figs. 2a-c).

Primitia variolata, var. paucipunctata, Jones and Holl, 1865. Ann. Mag. Nat. Hist., ser. 3, vol. xvi., p. 419, pl. xiii., figs. 6 c, d.

P. paucipunctata, Jones and Holl, 1886. Ibid., ser. 5, vol. xvii., p. 409, pl. xiv., figs. 3 a, b.

Observations.—The example here figured on Plate XV., Fig. 2, is somewhat more elongate than those of this species already known, but there is probably a great amount of variation in the carapace. In general outline the figured form referred to is, in its lateral aspect, closely comparable with the foregoing variety of P. elongata, but the edge view does not bear out the comparison. The scattered depressions on the hinder portion of the valves serve to distinguish this from related forms. Fig. 4 of Plate XIV. is probably an immature specimen, but is more typical in its shape.

P. paucipunctata is a well-known form in the English Silurian strata.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Primitia striata, Krause. (Pl. XV., Figs. 3a-c).

Primitia ? striata, Krause, 1891. Zeitschr. Deutsch. Geol. Gesellsch., p. 496, pl. xxxi., figs. 4, 5 a-c.

Observations.—Our specimen, which is unfortunately imperfect, differs from the above species in having an acuminate anterior extremity, instead of being squarely rounded off, as in the examples figured by Dr. Krause; and the general shape of the carapace is more elongate. The species is, however, a very variable one, and the present example may therefore be regarded, in the absence of other specimens, as merely a sub-variety; like the original examples, this one is longitudinally and interruptedly striate. Krause's type specimens came from the Silurian drifted block of Scandinavian limestone, North Germany.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Primitia semicircularis, Jones and Holl. (Pl. XV., Figs. 4a-c).

Primitia semicircularis, Jones and Holl, 1865. Ann. Mag. Nat. Hist., ser. 3, vol. xvi., p. 424, pl. xiii., figs. 10, a-c.

Observations.—The specimen figured by Jones and Holl from the Silurian drifted limestone of N. Germany almost exactly matches our specimen, but the latter is not quite so acutely produced anteriorly.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Primitia unicornis, Ulrich sp. (Pl. XV., Figs. 6a, b).

Leperditia unicornis, Ulrich, 1879. Journ. Cincinn. Nat. Hist. Soc., vol. ii., p. 10, pl. vii., fig. 4.

Primitia unicornis, Ulrich sp., Jones, 1890. Quart. Journ. Geol. Soc., vol. xlvi., p. 7, pl. iv., figs. 8-13.

Observations.—This species shows a large amount of variation in its general shape, being typically faboid, with a shallow dorsal depression and a posterior tubercle usually situated near the ventral angle, but in our specimen seen near the middle of the posterior border. P. unicornis has hitherto been recorded only from the Upper Ordovician of Wales and the United States.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Family *Cytheridae.*

Genus *Xestoleberis*, G. O. Sars.

Xestoleberis holliana, sp. nov. (Pl. XIII., Figs. 3a-c).

Description.—Carapace elongate ovoid. Seen from the side elongate or subrectangular, dorsal margin slightly convex, rounded at the ends; anterior margin meeting the ventral border bluntly, and forming a slightly salient angle; the pos-

terior margin makes a wide curve towards the ventral border, meeting it at an obtuse angle. Edge view sub-triangular, very thick posteriorly, gradually tapering towards the front. End view sub-triangular and inflated, but flattened on the ventral surface and somewhat depressed along the dorsal line. Valves slightly unequal. Surface of valves smooth or feebly punctate.

Dimensions.—Length of carapace, .94 mm.; height, .42 mm.; thickness, .64 mm.

Observations.—This species seems to show decided affinities towards Xestoleberis corbuloides, Jones and Holl sp.[1] It differs from it, however, in the greater angularity and width of the posterior extremity of the valves. I have taken the opportunity to name this species after Dr. H. B. Holl, F.G.S., who did so much good work on Palaeozoic Ostracoda in conjunction with Professor T. Rupert Jones.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Xestoleberis lilydalensis, sp. nov. (Pl. XIV., Figs. 1a-c., 5a-c, 8a, b.

Description.—Carapace seen from the side narrow-oblong; ends unequally rounded; the posterior extremity narrow and sharply rounded; the anterior, broadly curved and terminating somewhat abruptly at the ventral angle, forming by the development of flanges a small beak-like projection; dorsal margin gently convex, ventral nearly straight. Surface sparsely punctate. Edge view subovate, tumid, greatest thickness a little in front of the posterior third, and tapering more or less evenly to the anterior end. End view depressed cordate.

Dimensions.—Spec. 1. Length of carapace, .53 mm.; height, .21 mm.; thickness, .32 mm.

Type.—Spec. 2. Length of carapace, .78 mm.; height, .35 mm.; thickness, .46 mm.

Observations.—An Ordovician Xestoleberis (X. wrightii) has been figured and described from the Chair of Kildare, Leinster,

1 Cythere corbuloides, Jones and Hall, Ann. Mag. Nat. Hist., ser. 4, vol. iii., 1869, pp. 211, 212, pl. xv., figs. 4a-e, 5a, b.
Xestoleberis corbuloides, *Id.*, *ibid.*, ser. 5, vol. xix., 1887, p. 410.

Ireland, by Professor Jones and to which form the next variety described is assigned. The present specimens, although agreeing with the former in thickness and edge view of the carapace, are quite distinct, since X. wrightii has an ovate form of carapace.

The present specimens show considerable variation, but the same general characters serve to connect them specifically.

Fig. 5, it should be noticed, is shown with the ventral side uppermost, whilst in Fig. 8 it is turned downwards. In the latter figure the posterior edge of the left valve is apparently displaced beyond the edge of the opposing one.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Xestoleberis wrightii, Jones, *var.* **oblonga,** nov. (Pl. XV., Figs. 1a, b).

Observations.—The published figures[1] of this species are not nearly so elongate as our specimen, and since the latter is longer and altogether larger than the already known forms of the species it may be distinguished as a variety of X. wrightii.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Genus *Aechmina*, Jones and Hall.

Aechmina jonesi, sp. nov. (Pl. XIV., Figs. 11a, b).

Description.—Carapace tumid, with a slightly concave ventral, and strongly convex dorsal border; ends unequally rounded. Near the ventral border of each valve and towards the posterior extremity there is a short, blunt and oblique spine. Edge view subovate.

Dimensions.—Length of carapace, .82 mm.; height, to base of spine, .57 mm.; thickness, about .6 mm.

Observations.—The above form seems to bear intermediate characters between A. byrnesi Miller sp. Upper Ordovician)[2] and A. cuspidata Jones and Holl. (Silurian).[3]

1 Xestoleberis wrightii, Jones, 1890: Quar. Journ. Geol. Soc., vol. xlvi., p. 28, pl. iv., figs., 14, 15a-c.

Xestoleberis (?) aff. wrightii, Jones, Krause: Zeitschr. Deutsch. Geol. Gesellsch., 1891, p. 512, pl. xxxiii., figs. 9a-c.

2 Cincinn. Quar. Journ. Sci., vol. i., 1874, p. 123, fig. 10.

3 Ann. Mag. Nat. Hist., ser. 4, vol. iii., p. 218, pl. xiv., fig. 8 and woodcut, fig. 2.

I have named this species after the doyen of workers on the fossil Ostracoda, Professor T. Rupert Jones, F.R.S., and who first imparted to me an interest in this group of fossils.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Family *Cypridae.*

Genus *Argilloecia*, G. O. Sars.

Argilloecia acuta, Jones and Kirkby. (Pl. XV., Figs. 6a-c).

Argilloecia aequalis, var. acuta, Jones and Kirkby, 1895. Ann. Mag. Nat. Hist., ser. 6, vol. xvi., p. 457, pl. xxi., fig. 8.

Observations.—Both the above species and the variety were originally described from the Lower Carboniferous Limestone series of Yorkshire and the Lake District of England. Our specimen is indistinguishable from the variety acuta in every particular, so that for the present we may regard it as a form that has persisted throughout Devonian times. The so-called variety is here recorded in the specific sense, as it seems sufficiently distinct from A. aequalis,[1] and is, so far as we know, the older form, judging from the present occurrence.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Family *Bairdiidae.*

Genus *Macrocypris*, G. S. Brady.

Macrocypris flexuosa, sp. nov. (Pl. XIII., Fig. 6).

Description.—Carapace, elongate, siliquate and flexuose; seen from the side, highest in the middle; dorsal edge boldly rounded in the centre, and concave at both ends; ventral margin strongly convex in the middle, sloping gently to the acuminate anterior extremity; posterior end probably much attenuated, but partly wanting in our specimen. Edge view elongate-ovate with compressed and attenuate extremities.

Dimensions.—Length of carapace when perfect, about 2.07 mm.; greatest width, .64 mm.; thickness, .46 mm.

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1 Jones and Kirkby: Ann. Mag. Nat. Hist., ser. 5, vol. xviii., 1886, p. 263, pl. ix., figs. 6a, b.

Observations.—The nearest allied palaeozoic Macrocypris which may be at all compared with the above form is Macrocypris vinei, Jones.[1] M. vinei, however, does not, in any of its varieties, possess an acute anterior, nor so sloping an antero-ventral margin; moreover there is no attenuation of the posterior extremity as in our form. M. flexuosa very nearly approaches the recent M. tenuicauda, G. S. Brady,[2] in general form.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Macrocypris (cf.) **vinei**, Jones. (Pl. XIV., Figs. 7a-c).

Macrocypris vinei, Jones, 1887. Ann. Mag. Nat. Hist., ser. 5, vol. xix., p. 179, pl. iv., figs. 1-3, and woodcut.

M. vinei, Jones, 1887. Silur. Ostrac. Gothland, p. 6.

M. vinei, Jones, 1888. Ann. Mag. Nat. Hist., ser. 6, vol. i., p. 396, pl. xxii., figs. 1 a-c, 2.

Observations.—The Lilydale specimens differ principally in the higher and more flexuose carapace, the sloping anterior, and the more evenly rounded posterior, extremity. The above species, to which ours seems closely related, if not identical, is not uncommon in the Silurian of Gotland.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Genus *Bythocypris*, G. S. Brady.

Bythocypris holli, Jones. (Pl. XIV., Figs 9a, b, young form; Pl. IV., Figs. 1a-c ♂, Figs. 2a-c ♀).

Bythocypris hollii, Jones, 1887. Ann. Mag. Nat. Hist., ser. 5, vol. xix., p. 184, pl. v., figs. 1 a, b, 2; pl. vi., figs. 3 a, b, 4 a, b.

Observations.—This fine species is distinguished by its smooth, reniform and nearly symmetrically ended carapace, its semicircular back and gently sinuous ventral border. It is a

1 Ann. Mag. Nat. Hist., ser. 5, vol. xix., 1887, p. 179, pl. iv., figs. 1-3 and woodcut.
2 Rep. Chall. Zool., pt. iii., 1880, p. 41, pl. ii., figs. 1a-f.

well-known form in the Silurian of England and Gotland, and has also occurred in the Scandinavian limestone blocks in the drift of North Germany. It is interesting to note the variation in the carapace of the forms now figured, probably due to sexual differences. Somewhat similar varieties have been figured by Jones (loc. supra cit.). The example with a high carapace may be distinguished from B. phillipsiana, J. and H. sp.[1] by the nearly semicircular form of its valve.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Bythocypris caudalis, Jones. (Pl. XV., Figs. 7a-c).

Bythocypris caudalis, Jones, 1889. Ann. Mag. Nat. Hist., ser. 6, vol. iv., p. 270, pl. xv., figs. 2 a-c, 3 a-c.

Observations.—The peculiar posterior extremity of this form is fairly well seen in the present example; and the compression of the carapace serves to distinguish it from the otherwise similarly-shaped Pontocypris mawii, Jones,[2] as also does the larger size of the left valve.

This species also occurs at Wisby, Gotland.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

Bythocypris phaseolus, *var.* **elongata**, Jones. (Pl. XV., Figs. 5a, b).

Bythocypris phaseolus var. elongata, Jones, 1889. Ann. Mag. Nat. Hist., ser. 6, vol. iv., p. 271, pl. xv., figs. 8 a-c.

Observations.—This variety was discovered by Lindström in the red clay of Wisby, Gotland (base of the Stricklandinia Maris). Our figured example is even more elongate than the Gotland specimen described by Prof. Jones, but otherwise agrees with it.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

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1 cf. Jones: Ann. Mag. Nat. Hist., ser. 5, Vol. xix., 1887, p. 187, pl. v., figs. 3a, b, 4a-c.
2 Ann. Mag. Nat. Hist., ser. 5, vol. xix., 1887, p. 182, pl. iv., figs. 4a-d, 6, 7.

Family *Cypridinidae.*

Genus *Cyprosina*, Jones.

Cyprosina, sp. (Pl. XVI., Fig. 4; Pl. XVII., Fig. 1).

Observations.—This somewhat fragmentary specimen seems to agree most nearly with the genus Cyprosina, and is apparently a left valve. It differs from C. whidbornei[1] of the Devonian of England in having more compressed ends and a greater breadth at the posterior extremity. This specimen was collected by the Rev. A. W. Cresswell, M.A.

Locality and Horizon.—Cave Hill, Lilydale. Silurian (Yeringian).

PHYLLOCARIDA.

Family *Ceratiocaridae.*

Genus *Ceratiocaris*, McCoy.

Ceratiocaris pritchardi, sp. nov. (Pl. XVII., Figs. 2, 2a).

Description.—Carapace pyriform, deep behind, narrower in front and rather acute; back gently curved; ventral margin forming a bold curve and meeting the posterior margin at a sharp angle, whilst it curves more gently towards the anterior region, where it is somewhat concave. Abdominal margin deeply concave. Surface gently rounded near the back and anteriorly, more tumid along the ventral side and terminating in a narrow and conspicuous flange. From about the middle of the carapace to the flattened ventral margin the surface is relieved by elongate tubercular ridges and incised striae running generally parallel with the ventral border.

Segments and telson not known.

Dimensions of Carapace.—Greatest length, 23 mm.; greatest width, 14 mm.

Observations.—The carapace of C. pritchardi is quite distinct, in its general shape, from any known species of Ceratiocaris, the nearest approach to it being shown in C. halliana, Jones

1 Geol. Mag. Dec. [illegible], p. [illegible], pl. [illegible], figs. [illegible].
Ann. Nat. Hist., ser. [illegible], p. 34[illegible], pl. [illegible], figs. [illegible].

and Woodward.[1] In that species, however, the ventral margin is less strongly curved, and the carapace more elongate; the superficial ornament, morever, is merely striate or finely wrinkled.

Locality and Horizon.—Wandong, Victoria. Silurian (Melbournian). Presented by G. B. Pritchard, Esq.

Ceratiocaris, (cf.) **murchisoni,** Agassiz, sp. (Pl. XVII., Figs. 5, 6).

Onchus murchisoni, Agassiz, 1839. In Silur. Syst., p. 607, pl. iv., fig. 10 (not figs. 9 and 11); Onchus, fig. 63?; Ichthyodorulite, fig. 64.

Leptocheles (murchisoni), McCoy, 1851. Synops. Brit. Pal. Foss., Fasc. 1, p. 176.

Ceratiocaris murchisoni (Ag.), Jones and Woodward, 1888. Brit. Pal. Phyll., pt. i. (Pal. Soc. Mon.), p. 16, pl. iii., figs. 4 a, b; pl. iv., figs. 1-3; pl. v., fig. 3; pl. vi., figs. 1, 2.

Observations.—The above species seems to be represented in collections only by caudal appendages, no example of a carapace having been found directly associated with those remains. A very close analogy exists between our specimens and the above-named species. In connection with the specimens now under consideration it is interesting to note that the late Sir F. McCoy had, many years ago, tentatively labelled them "Leptocheles," but had apparently made no specific comparison, presumably on account of the unpromising appearance of the matrix in which the impressions occur. A wax squeeze taken from these casts in sandstone give surprisingly good results, and even the pittings on the sides of the spines can be in this way distinctly made out in two of the specimens. In England C. murchisoni is found in the Ludlow or uppermost Silurian series.

Locality and Horizon.—Kilmore, Range on E. side Common Reserve, Geol. Surv. Vict. Bb 23. Silurian.

(?) **Ceratiocaris,** sp. (Pl. XVII., Figs. 7, 8).

Observations.—The specimens figured are copied from wax squeezes made from specimens which are not uncommon in the

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1 Brit. Pal. Phyllopoda (Phyllocarida), pt. 1 (Pal. Soc. Mon.), 1888, p. 26, pl. ii., figs. 1, 2, 3, 4 (?); pl. iv., figs. 5, 6; pl. v., figs. 6a, 6b (?).

sandstones of the Moonee Ponds Creek. They are undoubtedly remains of phyllopodous crustacea allied to, if not identical with, Ceratiocaris, and seem to be casts of the strong abdominal appendage or style.

Some of the specimens show a fine striation running obliquely to their length and passing over the ridge, or arranged in a V-shaped pattern, such as is often seen on the appendages of phyllocarids.

Similar fragments have been figured by Barrande.[1] The style shown in the figure of Ceratiocaris papilio, Salter, given by Jones and Woodward[2] bears a close resemblance to our specimens.

Locality and Horizon.—Moonee Ponds Creek, near Flemington ("Royal Park"). Silurian (Melbournian).

Family *Rhinocaridae*.

Genus *Dithyrocaris*, Scouler.

Dithyrocaris praecox, sp. nov. (Pl. XVII., Fig. 3.)

Description.—Carapace subquadrate; anterior notch of medium size compared with known species, angular; posterior border angulated, with evidence of posterior spines. Surface of carapace numerously pitted, especially along the ventral borders. Meso-lateral ridges, apparently smooth, strong, and sinuously curved. Appendages, one stout caudal joint, with spinous terminations.

Dimensions.—Length of carapace, 17 mm.; approximate width, 13 mm.; length of caudal appendage, 9 mm.

Observations.—This specimen, although somewhat crushed and relatively displaced, shows decided affinities with the genus Dithyrocaris. The hinge-line, so far as can be seen, is comparable with that genus in having a rugose edge. In its medium-sized angular anterior notch and circular surface pittings this species resembles D. testudinea, Scouler sp., from the

1 Syst. Sil., vol. i., Supplement, 1872, p. 459, pl. xxxiii., figs. 25, 25a.
2 Brit. Pal. Phyllopoda (Phyllocarida), pt. i. (Pal. Soc. Mon.), 1888, pl. xii., fig. 1.

British Carboniferous formation,[1] but it differs in having a more quadrate carapace, and there are no indications of the linear ornamentation seen in that species.

Locality and Horizon.—Merri Creek, sects. 2 and 3, Kalkallo. Geol. Surv. Vic. Bb 3. Silurian.

Family *Peltocaridae.*

Genus *Aptychopsis*, Barrande.

Aptychopsis victoriae, sp. nov. (Pl. XVII, Fig. 4).

Description.—Carapace sub-ovate; having a rather deep and narrow rostral notch. Valves broadly rounded anteriorly, sharply terminating at the notch; sides almost parallel with the mesial suture. Posterior portion wanting in the type specimen. Surface more or less concentrically grooved or lineated. Internal view of mesial suture ridgelike and rugose.

Dimensions.—Approximate length, 21 mm.; width of carapace, 16 mm.

Observations.—This species differs from the hitherto known forms of Aptychopsis in the squareness of the carapace and in the form of the anterior notch.

Locality and Horizon.—Moonee Ponds Creek ("Royal Park"), near Flemington. Silurian.

CORRIGENDA TO "NEW OR LITTLE-KNOWN VICTORIAN FOSSILS," PART III.

(Vol. xvi., pt. ii., of these Proceedings).

P. 337, line 12 from bottom, read "Figs. 4 and 6."
P. 340, line 3 from bottom, delete "8."
P. 342. In explanation of plate, after Fig. 6 insert "Styliola fissurella, var. multistriata."

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1 Argas testudineus, Records of General Science (Thomson's), vol. i., 1835, pp. 137, 141, fig. 3.

Dithyrocaris testudinea, Scouler sp., Jones and Woodward, Brit. Pal. Phyllop. (Pal. Soc. Mon.), pt. iii., 1898, p. 145, pl. xix., figs. 7-9, etc.

CORRIGENDA TO PAPER "ON A COLLECTION OF UPPER PALAEOZOIC AND MESOZOIC FOSSILS FROM WEST AUSTRALIA AND QUEENSLAND."

(Vol. xvi., pt. ii., of these Proceedings).

P. 311, line 5 from top, for pl. "i." read pl. "xxvii."

P. 325, line 3 from bottom, for "Allorisma maxima" read "Allorisma maximum." Also p. 333.

P. 329, line 14 from bottom of page, for "Ctenostreon pectiniformis" read "Ctenostreon pectiniforme. Also pp. 333 and 335.

P. 330, line 7 from bottom, for "Normannites australe" read "Normanites australis." Also p. 333.

Note to above paper on West Australian and Queensland Fossils.—On p. 326 the following reference should be inserted under Goniatites micromphalus, and the name read as Agathiceras (?) micromphalum :—

"Agathiceras (?) micromphalum, Morris sp., Foord and Crick, 1897, Cat. Foss. Ceph. Brit. Mus., pt. 3, p. 271, woodcut, fig. 132 (p. 272)." [According to Messrs. Foord and Crick the suture-line and the general form of this shell seem to ally the species with Agathiceras ; so that the species is now regarded as almost certainly belonging to that genus. My thanks are due to Mr. Crick for pointing out the omission].

EXPLANATION OF PLATES XIII.-XVII.

(Numbers enclosed in square brackets refer to registered specimens in the Museum).

PLATE XIII.

(All the figures on this plate magnified 28 diameters).

Fig. 1.—Primitia subtrigonalis, sp. nov. a, Carapace from the right side ; b, dorsal view ; c, end view. [5393].

" 2.—Primitia punctata, Jones. a, Carapace from the right side ; b, dorsal view ; c, end view. [5394].

" 3.—Xestoleberis holliana, sp. nov. a, Carapace from the left side ; b, ventral view ; c. end view. [5406].

Fig. 4.—Primitia semicultrata, sp. nov. a, Carapace from the left side; b, dorsal view; c, end view. [5395].

„ 5.—Primitia (?) matutina, Jones and Holl. a, Carapace from the right side; b, dorsal view. [5396].

„ 6—Macrocypris flexuosa, sp. nov. a, Carapace from the right side; b, ventral view. [5413].

„ 7.—Primitia reticristata, Jones. a, Carapace from the right side; b, dorsal view. [5397].

„ 8.—Primitia *cf.* obsoleta, Jones and Holl. a, Carapace from the right side; b, dorsal view; c, end view. [5398].

Plate XIV.

(All the figures on this plate magnified 28 diameters).

Fig. 1.—Xestoleberis lilydalensis, sp. nov. a, carapace from the left side; b, dorsal view; c, end view. [5408].

„ 2.—Primitia halli, sp. nov. a, Carapace from the right side; b, dorsal view; c, end view. [5399].

„ 3.—Primitia elongata, Krause, var. nuda, Jones. a, Carapace from the right side; b, dorsal view; c, end view. [5400].

„ 4.—Primitia paucipunctata, Jones and Holl. a, Carapace from the right side; b, dorsal view; c, end view. [5401].

„ 5.—Xestoleberis lilydalensis, sp. nov. a, Carapace from the left side; b, ventral view; c, end view. [5409].

„ 6.—Argilloecia acuta, Jones and Kirkby. a, Carapace from the left side; b, dorsal view; c, end view. [5412].

„ 7.—Macrocypris *cf.* vinei, Jones. a, Carapace from the left side; b, ventral view; c, end view. [5414].

„ 8.—Xestoleberis lilydalensis, sp. nov. a, Carapace from the right side (showing part of displaced left valve); b, ventral view. [5407].

Fig. 9.—Bythocypris holli, Jones. (Young form). a, Carapace showing right valve; b, dorsal view. [5417].

„ 10.—Aparchites subovatus, Jones. a, Carapace from the right side; b, ventral view; c, end view. [5391].

„ 11.—Aechmina jonesi, sp. nov. a, Carapace from the right side; b, dorsal view. [5411].

PLATE XV.

(All the figures on this plate are magnified 28 diameters).

Fig. 1.—Xestoleberis wrighti, Jones, var. oblonga nov. a, Carapace from the right side; b, dorsal view. [5410].

„ 2.—Primitia paucipunctata, Jones and Holl. a, Carapace from the left side; b, dorsal view; c, end view. [5402.]

„ 3.—Primitia striata, Krause. a, Carapace from the right side; b, ventral view; c, end view. [5403].

„ 4.—Primitia semicircularis, Jones and Holl. a, Carapace from the left side; b, dorsal view; c, end view. [5404].

„ 5.—Bythocypris phaseolus, var. elongata, Jones. a, Carapace from the right side; b, ventral view. [5419].

„ 6.—Primitia unicornis, Ulrich sp. a, Carapace from the right side; b, ventral view. [5405].

„ 7.—Bythocypris caudalis, Jones. a, Carapace from the right side; b, dorsal view; c, end view. [5418].

„ 8.—Primitia trigonalis, Jones and Holl. a, Carapace from the right side; b, ventral view; c, end view. [5392].

PLATE XVI.

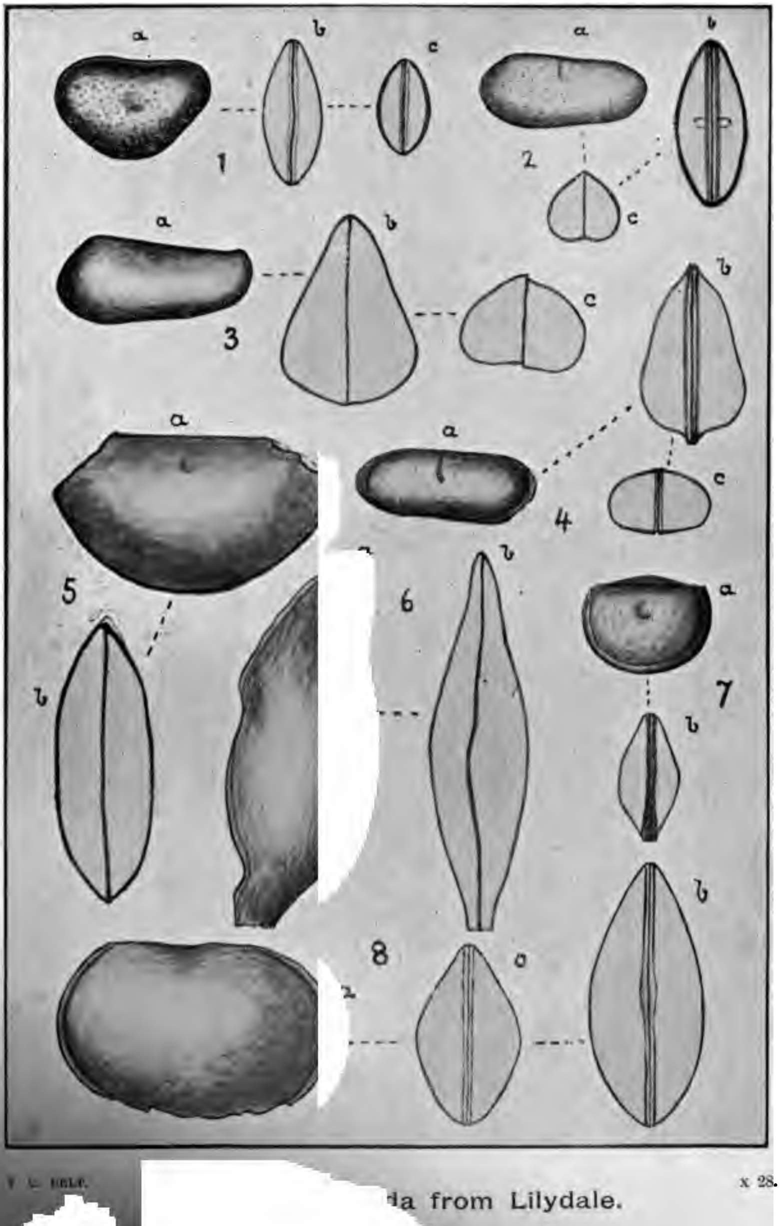
(All the figures on this plate are magnified 28 diameters).

Fig. 1.—Bythocypris holli, Jones. (♂). a, Carapace from the right side; b, ventral view; c, end view. [5416].

„ 2.—Bythocypris holli, Jones. (♀). a, Carapace from the right side; b, ventral view; c, end view. [5415]

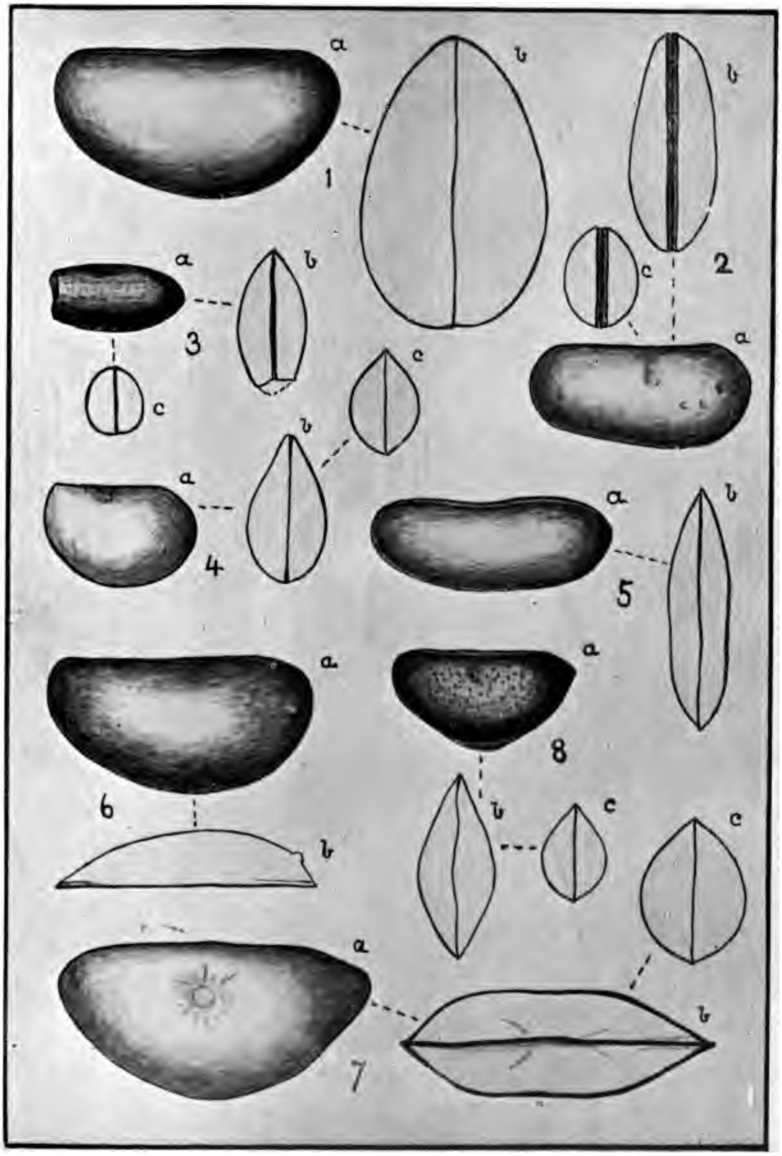
„ 3.—Isochilina labrosa, Jones. a, Right valve; b, view. [5390].

„ 4.—Cyprosina, sp. Left valve. [1219]



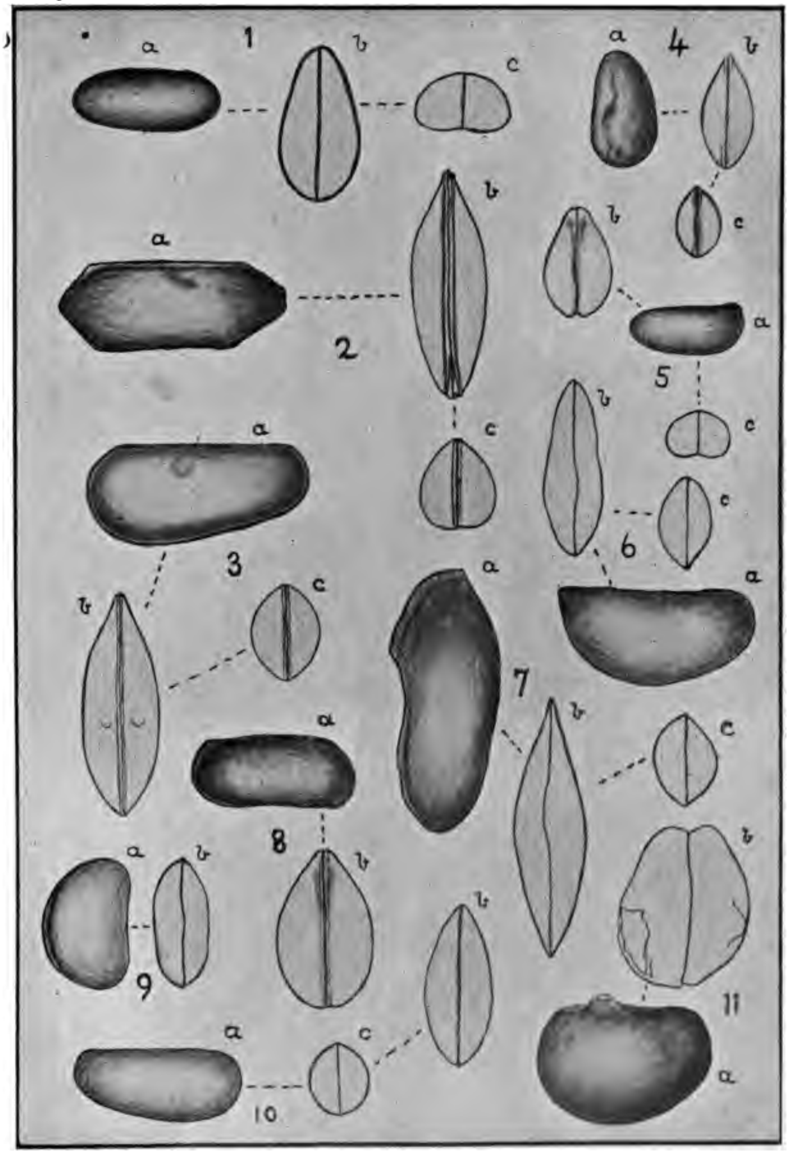
[illegible] DELT. x 28.

...da from Lilydale.



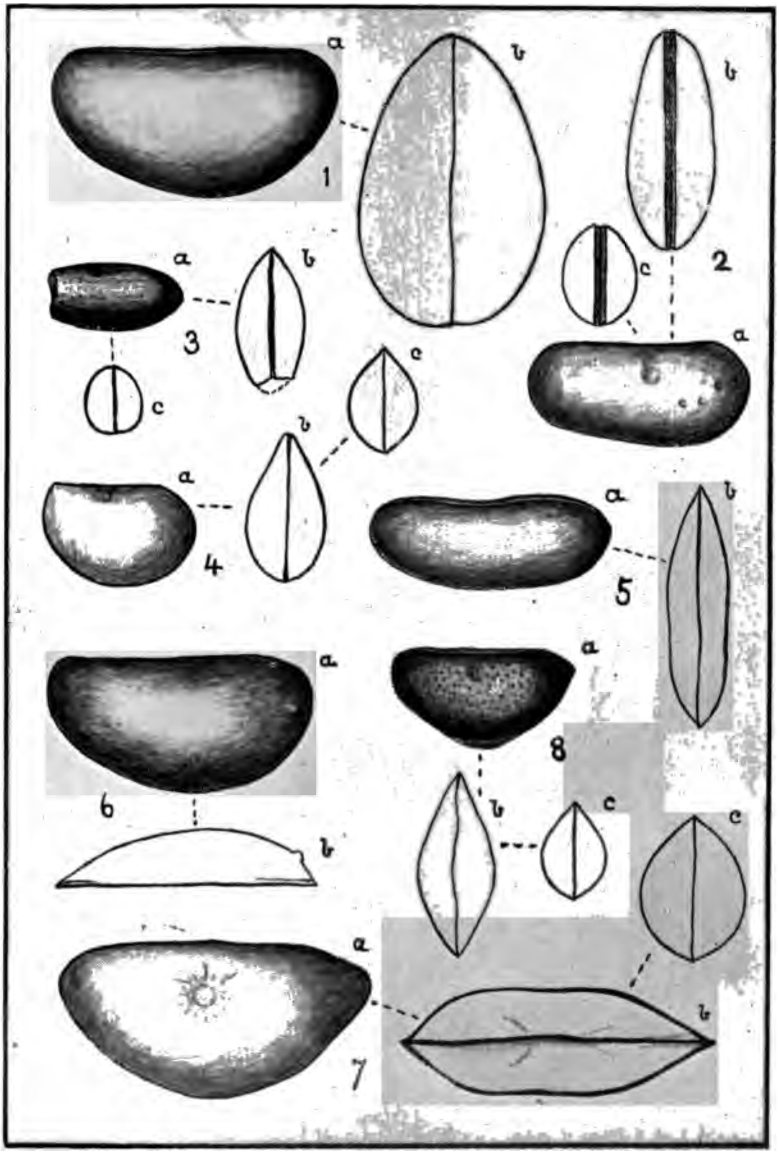
F. C. DELT. x 28.

Silurian Ostracoda from Lilydale.



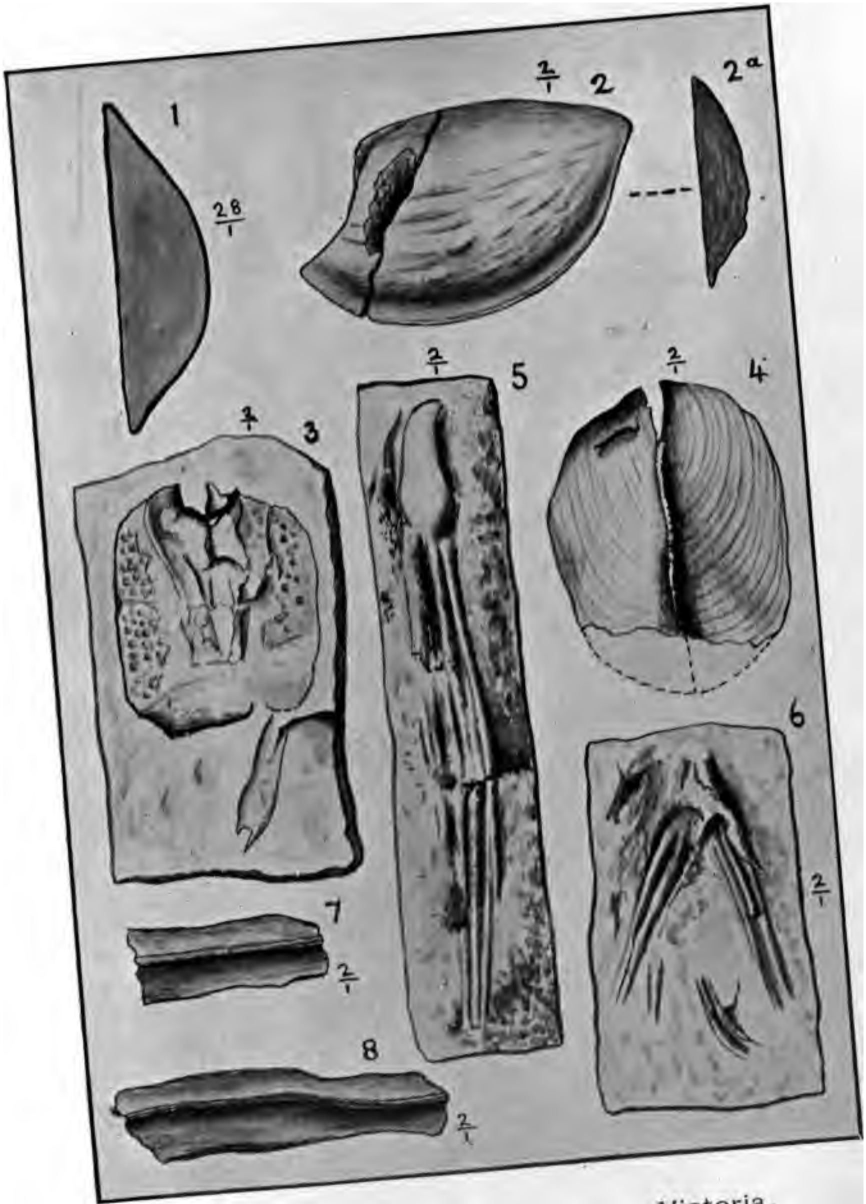
F. C. DELT. x 28.

Silurian Ostracoda from Lilydale.



F. C. DELT.   x 28.

Silurian Ostracoda from Lilydale.



F. C. DELT.

Silurian Phyllocarida, etc., from Victoria.

PLATE XVII.

Fig. 1.—Cyprosina, sp. Edge view of valve. [1219]. × 28.

„ 2.—Ceratiocaris pritchardi, sp. nov. Carapace from right side; 2a, profile across the median line of one valve. [1918]. × 2.

„ 3.—Dithyrocaris praecox, sp. nov. Carapace, with caudal appendage. [4662]. × 2.

„ 4.—Aptychopsis victoriae, sp. nov. Carapace. [2238]. × 2.

„ 5.—Ceratiocaris (cf.) murchisoni, Agassiz, sp. Telson, showing attached head. [447]. × 2.

„ 6.—Ceratiocaris (cf.) murchisoni, Ag., sp. Stylets. [450]. × 2.

„ 7, 8.—? Ceratiocaris, sp. Probably fragments of abdominal appendage (style). [5387-8]. × 2.

Art. X.—*Contributions to the Palaeontology of the Older Tertiary of Victoria.*

Gastropoda.—Part II.

By G. B. PRITCHARD,

Lecturer on Geology, etc., Working Men's College, Melbourne.

(With Plates XVIII. and XIX.).

[Read 14th July, 1904].

In this paper I desire to add to our knowledge of the molluscan fauna of the Older Tertiary deposits by the description and figures of several new species of interest, together with notes, additions, and corrections on species that have previously been described.

The species referred to in the following pages are as follows:

Clavella bulbodes, Tate.
Clavella platystropha, sp. nov.
Columbella balcombensis, sp. nov.
Columbella approximans, sp. nov.
Columbella woodsi, nom. mut.
Pleurotoma selwyni, sp. nov.
Apiotoma bassi, sp. nov.
Turbo hamiltonensis, sp. nov.
Collonia geelongensis, sp. nov.
Collonia otwayensis, sp. nov.
Cantharidus serratulus, sp. nov.
Astele millegranosa, sp. nov.
Eutrochus fontinalis, sp. nov.
Bankivia howitti, sp. nov.
Pleurotoma murrayana, sp. nov.
Pleurotoma granti, sp. nov.

Clavella bulbodes, Tate. (Pl. XVIII., Figs. 2, 3.)

1888. Fusus bulbodes, Tate. T.R.S. S.A., vol. x., Gast., pt. i., pp. 139, 140 (pp. 49, 50, in reprint), pl. 7, f. 8.

1892. Fusus bulbodes, Pritchard. Cat. Tert. Foss. Austr., S.A. School of Mines Report, p 195 (p. 27 in reprint).

1894. Clavilithes bulbodes, Tate. P.R.S. N.S.W., vol. xxviii., p. 170.

1901. Clavella bulbodes, Pritchard. P.R.S. Vic., vol. xiv., n.s., pt. i, p. 48.

Description.—This species was founded on young specimens, and judging from the localities originally indicated by Professor Tate, it seems that two species have on this account been confused. For the usual specimens from Muddy Creek appear to me to represent quite a distinct species from that obtainable at Mornington and several other localities, though I possess one imperfect example of this species from Muddy Creek, and I therefore judge it as comparatively rare.

Professor Tate's description runs as follows:—"Shell long, fusiform with a rapidly narrowing spire of subimbricating whorls, terminating in a large ovoid summit. Whorls eight, the first somewhat globose, the next very narrow, smooth and bicarinated, the third nearly flat, shining and spirally scratched; the other whorls gradually becoming more and more obtusely angled and swollen round the anterior part, being very contracted at the anterior suture, and flatly sloping to the posterior suture; encircled with raised threads (about 15 on the penultimate whorl) narrower than the interspaces, which are traversed by close-set striae. Last whorl tumid and rounded at the periphery, rapidly contracted at the base into a long, narrow, straight canal; the surface tessellated by transverse threads and stouter spiral lirae."

As these particulars and the figure given agree with the fairly common Mornington or Schnapper Point specimens, I intend to retain the name of Clavella bulbodos for this species, but as the dimensions show only young specimens a few further remarks on the adult specimens may not be out of place.

Shell large and strong, composed of nine rapidly enlarging spire-whorls without the remarkably large mammillate embryo, the spiral sculpture is distinctly developed on the first five whorls, but tends to become obsolete on the penultimate and body whorls, the body whorl usually only showing the mere

trace of five or six broadly separated spiral threads wheré the whorl has its greatest convexity; the transverse folds parallel to the lines of growth on the other hand increase in strength and irregularity till on the base of the body-whorl the whole surface is broken up by prominent undulations or growth folds of varying strength, the base shows no spiral sculpture or striations. The body-whorl falls away very rapidly to a long, straight, robust canal. Suture of penultimate and body-whorls somewhat canaliculate, outer lip slightly ascending on the body-whorl and much thickened at its junction where there is a strong enamel pad of the posterior portion of the inner lip, the enamel of the inner lip spreads well down and thins out to the columella and is strongly margined by a groove at its outer edge. In general aspect the adult retains the habit of the young shell.

Dimensions.—Length without the embryonic whorls, 200 mm.; estimated perfect length, about 210 mm.; breadth, 84 mm.; length of aperture, 56 mm.; breadth of aperture, 32 mm.; length of aperture and canal, 116 mm.

Locality.—Clays of the Old Cement Works, Balcombe's Bay, Clays of Grice's Creek and Coast sections, Mornington. Coast section Gellibrand River; Clays of the Newport shaft; Clays of Orphanage Hill, near Geelong, and Murghebuloc, Barwon River; Lower Beds of Muddy Creek.—Balcombian.—Eocene.

Clavella platystropha, sp. nov. (Pl. XVIII., Figs. 4, 5).

Description.—Shell large, elongate fusiform, with an elongate spire composed of rather flattened whorls with a much elongated slender columella and canal.

Spire whorls nine in the adult form without the mammillate embryo. The first two spire whorls flat, the third slightly convex below the middle, the fourth and fifth with increasing submedian convexity, posterior slope long and gradual and flattened or slightly concave to the suture, slope to the anterior suture rather more sudden, the remaining spire-whorls flattened or only slightly but regularly convex. Body-whorl flatly convex to the periphery, thence falling away very rapidly to the snout. On the first spire-whorls the sculpture is very faint, on the

second, third, and fourth, fine uniform spiral threads narrower than the interspaces make their appearance, on the fifth the threads open out somewhat and show some finer intercalated threads especially about the median portion of the whorl, thence the spiral sculpture tends to become obsolete, the sixth whorl showing it more especially towards the posterior suture, thence it is difficult to discern any but the merest traces of spiral sculpture. The earlier whorls, especially the third and fourth, show under a lens very fine, regular close-set striae of growth, distinct in the interspaces, a few increasing in strength on the fourth so as to cross the spiral threads with a slight node and giving rise to a minute tesselation with three or four finer striae in the interspaces, thence these stronger transverse threads develop into irregular folds of growth, whilst the finer transverse ornament is probably still retained to some extent in the finer lines of growth. Suture overlapping somewhat in the earlier whorls, but developing to a strongly canaliculate suture on the body-whorl. Aperture ovate, outer lip much thickened towards the posterior suture, thinning out and becoming sharp at the edge towards the canal. Columella long, rapidly tapering and straight, but for a thickening at the posterior end of the canal, in young specimens there are two slight undulations in the length of the columella, canal long and narrow.

Dimensions.—Length of a nearly complete adult specimen, 200 mm.; estimated length perfect, 215 mm.; breadth, 80 mm.; length of aperture, 65 mm.; breadth of aperture, 33 mm.; length of aperture and canal, 133 mm. A young specimen of five whorls gives, length, 65 mm.; breadth, 17 mm.; length of aperture, 13 mm.; breadth of aperture, 7 mm.; length of aperture and canal, 45 mm..

Locality.—Lower Beds of Muddy Creek sections near Hamilton, Western Victoria.—Balcombian.—Eocene.

This species is also represented in the National Museum Collection, Melbourne, by some specimens preserved in gypsum from the River Murray Cliffs.

Observations.—This is another very fine example of the genus Clavella, and is specifically distinct from C. bulbodes, Tate. The present species, though of something like the same propor-

tions of length to breadth as C. bulbodes, Tate, has an entirely different habit, the whorls being flattish and running right up to the suture, instead of being tumidly convex submedially and concave towards the suture, the suture is more canaliculate, the canal is longer and of a more tapering habit, the sculpture is much finer and becomes obsolete sooner. The general habit of this species is very much more of the type of C. longaevus than any other described Australian species.

Columbella balcombensis, sp. nov. (Pl. XVIII., Figs. 10, 11).

Description.—Shell small, tumidly fusiform, with a blunt apex of about three smooth shining and somewhat tumid embryonic whorls, the extreme tip inclined to be elevated. Embryonic whorls succeeded by three to five slightly convex spire-whorls, suture impressed, and the body-whorl rather attenuate towards the snout. The smooth embryo is in strong contrast to the highly sculptured whorls, and ends off abruptly against the spire ornament. The sculpture of the spire-whorls consists of fine close costulae and rather finer spiral threads which show most strongly in the interspaces between the costulae giving rise to a minute clathrate appearance, the spiral threads increase in strength towards the anterior of the shell, being most prominent on the anterior slope of the body-whorl and on the snout. The costulae on the penultimate whorl number about thirty-five to forty. Aperture ovate; canal very short and slightly bent to the right; outer lip varicosely thickened and lirate externally, bevelled off internally to a thin edge, fairly strongly denticulate within, the strongest and largest denticle being at the anterior end of the aperture; inner lip smooth and enamelled, columella somewhat twisted.

Dimensions.—Length of a four-whorled specimen, 9 mm.; breadth, 4 mm.; length of aperture and canal, 4.5 mm.; other specimens range 7.5 mm. by 3 mm.; 7 by 3 and 5.5 by 2.5; while a five-whorled specimen extends to length, 11.5 mm.; breadth, 5 m.m.

Locality.—Clays of the old Cement Works, Balcombe's Bay (Type), Grice's Creek and Coast sections, Mornington; sandy

clays and clays of Orphanage Hill, near Geelong, and along the Lower Moorabool Valley; Curlewis clays, and Belmont, near Geelong; Newport shaft; Murgheboluc, Barwon River; Inverleigh; Shelford; Lower Beds of Muddy Creek, near Hamilton, Western Victoria; clays of the coastal sections Gellibrand River.—Balcombian (except Curlewis and Belmont.—Barwonian).—Eocene.

Clays of the middle zone of the Spring Creek series, Bird Rock Bluff, near Geelong.—Jan Jukian.—Eocene.

Observations.—This is a well marked and characteristic little species entirely different from any other of our described species, and has been frequently quoted as C. clathrata, Tate, but as that name was never more than a manuscript one and as it has already been several times preoccupied for both recent and fossil species of this genus, the necessity for a new name is obvious.

Columbella approximans, sp. nov. (Pl. XVIII., Figs. 12, 13).

Description.—Of similar habit to the foregoing species, C. balcombensis, with a slightly exsert tip to the three smooth embryonic whorls succeeded by four other whorls, it differs strongly in its sculpture, bearing fewer bowed or backwardly curved costulae with very faint spiral lineations except towards the extreme anterior of the body-whorl. There are about thirteen costulae on the first whorl increasing to about twenty-two on the penultimate whorl. Outer lip strongly evaricose, and externally much more finely lirate than C. balcombensis, canal and columella also shorter. The contrast between the stronger development of the costulae and the weaker development of the spiral sculpture loses entirely for this species the clathrate appearance so characteristic of the foregoing.

Dimensions.—Length, 7 mm.; breadth, 3 mm.; length of aperture and canal, 3 mm.

Locality.—Clays of the Old Cement Works, Balcombe's Bay, Mornington.—Balcombian—Eocene. Also Curlewis, near Geelong.—Barwonian.—Eocene.

Columbella woodsi, nom. mut.

1878. Fusus funiculatus, T. Woods (non Reeve and others). P.L.S. N.S.W., p. 225, pl. 20, f. 1.

1888. Columbella funiculata, Tate. T.R.S. S.A., vol. x., Gast., pt. i., p. 132 (p. 42 in reprint).

1892. Columbella funiculata, Pritchard. Cat. Tert. Foss. Austr. Report S.A. School of Mines, p. 199 (p. 31 in reprint).

1903. Columbella funiculata, Dennant and Kitson. Cat. Cain. Foss. Aust., Rec. Geo. Surv. Vict., vol. i., pt. 2, p. 105.

Locality.—Clays of Orphanage Hill, Fyansford, Griffin's section, Moorabool Valley, and Curlewis near Geelong; clays and limestones of the Old Cement Works, Balcombe's Bay, Mornington, and Grice's Creek; Newport shaft; lower beds of Muddy Creek, near Hamilton, Western Victoria; Fishing Point, Aire River; Native Hut Creek and Shelford, near Inverleigh; clays of the coastal section, Gellibrand River.—Balcombian—Eocene.

Observations.—In the course of studying some of the species of this genus, I find that Columbella funiculata, T. Woods, originally described in the Proceedings of the Linnean Society of New South Wales, 1878, p. 225, pl. 20, f. 1, as Fusus funiculatus requires renaming on account of the preoccupation of this name by Reeve in 1846 and again by M. Souverbie in 1865.

This species has also appeared in several locality lists of fossils under the name of Columbella funiculatus, T. Woods, published both in South Australia and in Victoria.

Pleurotoma selwyni, sp. nov. (Pl. XIX., Fig. 1).

Description.—Shell tumidly fusiform or biconic, of medium size and build, with a comparatively broad body-whorl rapidly tapering to a very acute spire, with an aperture only slightly less than half the length of the shell, and a well-marked sinus on the keel. Embryo small, smooth, with an obtuse nucleus composed of about two whorls gradually merging into the spire-whorls. Spire-whorls eight, with a somewhat irregular and ascending overlap, giving rise to a canaliculate suture, Whorls

convex and furnished medially with two spiral lirae which mark exactly the position of the sinus; a third spiral thread is usually visible just above the anterior suture, and a fourth weak one just below the posterior suture on the earlier spire whorls, while a fifth makes its appearance on the penultimate and antepenultimate whorls and the posterior sutural thread becomes stronger; on the body-whorl below the sinus threads there are eight or nine stronger spiral lirae, and the space between the suture and the keel is strongly concave. The whole shell surface is finely spirally striate, the striae tending to be slightly undulatory owing to irregularities of growth, and increasing in strength towards the anterior of the shell. The spiral sculpture is crossed transversely by sinuated growth lines and striae of unequal strength. Sinus broad and deep, and distinctly margined by the lirae forming the keel. Aperture large, pyriform, and extending to a short, broad, open, slightly bent canal; outer lip thin and strongly arched at the middle, crenulate internally in conformity with the stronger spiral threads; columella margin smooth and slightly enamelled.

Dimensions.—Length, 38 mm.; breadth of body-whorl, 17 mm.; length of aperture, 19 mm.; breadth of aperture, 7 mm.; breadth of canal, 3 mm.; length of canal, about 5 mm. Smaller specimens range—length 28, breadth 14, 27 by 13, and 25 by 12.5.

Locality.—Lower beds of Muddy Creek, near Hamilton, Western Victoria; clays of the Old Cement Works, Balcombe's Bay, Mornington.—Balcombian.—Eocene.

Observations.—The placing of this species in Pleurotoma might at first sight be questioned, but it agrees more closely with this genus than any other; its characters place it in the same group as Pleurotoma septemlirata, Harris, which originally had the manuscript name of Pleurotoma perarata by Professor Tate, and is quoted under that name by Monsieur M. Cossman in his Essais de Paleoconchologie Comparée Deux. Liv., p. 77, where he speaks of it as an aberrant form of this genus.

The present species differs from P. septemlirata, Harris, in general habit being a relatively broader form, with a shorter and more rapidly tapering spire, a longer aperture, shorter and broader canal, broader sinus, and finer sculpture. It is also

interesting to note that some of the Muddy Creek examples of this species show regular rusty oval rings and patches especially on the sutural band, and other rusty markings in conformity with the sinus at fairly regular intervals, apparently a remnant of original colour markings. I name this species with much pleasure after Mr. A. R. C. Selwyn, the first Government geologist of this colony.

Variety laevis, var. nov. (Pl. XIX., Fig. 2).

There is another form which I can only regard as a variety of the above, showing a marked tendency towards the almost entire suppression of the strong spiral threads or lirae, thus intensifying the general biconic aspect of the shell.

Apiotoma bassi, sp. nov. (Pl. XIX., Fig. 11).

Description.—Shell fusiform, with a tapering spire less than half the length of the shell, a small but mammillate apex, whorls angulated by one strong keel, the base of the shell attenuated into a long, straight open canal, and a comparatively narrow aperture.

Embryo consisting of from one and a-half to two smooth whorls with the tip obliquely immersed, giving rise to the blunt mammillate appearance of the apex. Whorls number seven or eight, except in young specimens, strongly angulately keeled about the middle of each whorl or more usually a little above the middle of each whorl. On the earlier whorls the keel is bluntly nodulose; the nodules tend to become obsolete towards the body-whorl, where they are rarely present. The slope between the posterior suture and the keel is somewhat concave, intensifying the padoga-like appearance of the spire, suture well-defined and inclined to be margined. Surface of the shell covered with fine frequently interrupted spiral threads of unequal strength, crossed by stronger lines and undulations of growth, which frequently interfere with the regularity of the spiral threads. Sinus broad, moderately deep, and situated at the greatest concavity of the slope between the suture and the keel. Aperture long and rather narrow and gradually tapering

into the comparatively broad open canal. Outer lip thin and sharp at the edge, columella smooth, straight, slender, and tapering.

Dimensions.—Average specimens have a length of about 33 mm., by a breadth of 10 or 11 mm.; length of aperture and canal 20 mm.; greatest width of aperture, about 3.5 mm. Specimens on the large side range from about 45 to 50 mm. in length by a breadth of about 13 mm.; while small specimens range about 24 mm. in length bv 8 mm. breadth.

Locality.—Common from the clays of the Cape Otway section, near Point Flinders.—Jan Jukian.—Eocene.

Turbo hamiltonensis, sp. nov. (Pl. XIX., Fig. 4).

Description.—Shell turbinate, with a relatively elevated spire in the adult, elevation not striking in the young, robust and of medium size, consisting of about three convex whorls and a smooth embryo of about a whorl and a half, whorls ornate and strongly sculptured. Whorls convex, greatest convexity approximately medial, posterior slope to suture more gradual than anterior slope; suture well defined between the body and penultimate whorls, not ascending, the suture becomes less defined towards the embryo as the whorls overlap more, giving the young forms a more depressed appearance. Earlier whorls show three or four strong spiral threads on the upper or posterior slope, the one next to but usually the two next to the posterior suture showing a beaded coronation; this character is usually very indistinct or entirely absent from the remaining threads, and is continued right on to the body-whorl, where, however, it is not usually so clearly seen. The spiral threads number about seven or eight on the penultimate whorl, ten to greatest convexity on the body-whorl, varying in strength, some being rather broad flattened bands, the interspaces being narrow and deeply cut. Base of the shell bearing about ten strong threads which tend to become granulose near the umbilicus. Umbilicus small and rounded but deeply set. Aperture orbicular with the outer lip bevelled off from the interior to a sharp edge, posteriorly the inner lip is well defined by an enamel pad reaching to and into the umbilicus, anteriorly the columella end is somewhat patulous.

Dimensions.—Height, 34 mm.; greatest diameter, 37 mm.; diameter of aperture, 15 mm.; diameter of umbilicus, 5 mm.

Locality.—Upper beds of the Grange Burn, near Hamilton, Western Victoria.—Kalimnan.—Miocene.

Observations.—This species shows a close relationship with our common living species, Turbo undulatus, Martyn, and might, on a casual examination, be mistaken for that species, but the more striking distinguishing features are in the sculpture, the beaded ornament near the suture, the strongly sculptured base, the smaller umbilicus, the stouter columella, and the more erect aspect.

Collonia geelongensis, sp. nov. (Pl. XVIII., Figs. 8, 9).

Description.—Shell small, turbinate, and composed of about four slightly convex whorls. Apex blunt and depressed, with a smooth embryo. Suture distinct when not masked by one of the revolving keels.

Shell bearing four strong revolving keels or spiral threads on the earlier spire-whorls, these keels appear regularly beaded, the keels next the anterior and posterior sutures bearing slightly finer beads; on the penultimate and body-whorls the grooves between the keels become deeper, and the keels strong, and the beading resolves itself under the lens into forwardly projecting frills. Interspaces and keels very finely lamellosely striate transverse to the keels. Base very slightly convex, distinctly but minutely umbilicate, and ornamented with about three keels of the same character as on the upper part of the body-whorl, occasionally a minute fourth keel may be detected within the umbilicus. Peristome complete, orbicular and contracted internally, wider externally owing to the strong bevelling off from the interior to the thin edge, this characteristic appearance of the aperture is much intensified by the decurrency of the posterior suture.

Dimensions.—Greatest diameter, 5 mm.; height, 5 mm.; external diameter of aperture, 2.5 mm.; internal diameter of aperture, about 1 mm.

Locality.—Clays over Polyzoal Rock, Filter Quarries, Batesford, near Geelong.—Balcombian.—Eocene.

Collonia otwayensis, sp. nov. (Pl. XVIII., Fig. 6, 7).

Description.—Shell small, tumidly turbinate, rather solid, consisting of about five convex whorls with a blunt apex.

Whorls smooth to the unaided eye, but a lens shows fine regular spiral striae; whorls convex, suture faintly margined, earlier whorls more embracing than the body-whorl which runs down rapidly on the penultimate whorl with a more strongly defined suture. Base non-umbilicate, umbilical region margined by a faint ridge in the adult, which in more senile forms tends to break up into granules. Aperture roundly ovate, outer lip thickened, but bevelled off from the interior to a sharp outer edge. Columella slightly thickened and faintly effuse anteriorly, enamel of inner lip ascends to join the outer lip at the posterior extremity.

Dimensions.—Greatest diameter, 4 mm.; height, 4 mm.; diameter of aperture, 2 mm.; also specimens of height, 3 mm.; diameter, 3 mm.; and height 2.5 mm., by diameter 2 mm.

Locality.—Clays and sandy clays of the Cape Otway section near Point Flinders, and the Aire coastal section.—Jan Jukian.—Eocene.

Cantharidus serratulus, sp. nov. (Pl. XIX., Figs. 5, 6).

Description.—Shell of medium size, trochiform, of erect habit, acute spire, small apex, well impressed sutures, fine delicate ornament, and flat base.

Apex composed of a very small embryo of about a whorl and a half, the first whorl smooth and enrolled at right angles to the axis of general enrolment of the shell, and with the tip immersed, the remaining half-turn of the embryo is delicately costulate, thence the earlier clathrate sculpture of the spire prevails. Spire whorls eight, flat, or slightly convex between the sutures, the first three spire-whorls with a fine clathrate ornament owing to about three of the stronger spiral threads being crossed by numerous costulae of the same strength, with a slight beading or noding at their intersections. The remaining spire-whorls bear from five to eight or nine fine granulose spiral threads of varying strength; in some specimens fair uniformity prevails, whilst in other examples some two or three

threads are distinctly stronger than the rest, the others being much finer and even then not of equal strength. In the coarser form the beads of the spiral threads tend to become spiny denticles when examined under a lens. A fairly strong thread usually forms a keel at the base; the base is flat and carries about twelve unequal very finely granulose spiral threads. Aperture quadrate, pearly within, outer lip thin, sharp, and finely crenulate in conformity with the spiral threads. Columella slightly twisted, giving rise at the anterior end to a tooth-like projection. Anterior of the aperture somewhat profuse at the columella side.

Dimensions.—Height, 15 to 17.5 mm.; breadth, 9.5 to 12 mm.; height of aperture, 3.5 to 5 mm.; breadth of aperture, 5 to 6 mm. Also 12 mm. in length by 8.5 mm. in breadth and 10.5 by 7, 9 by 7, 7 by 5, and 6 by 4 for the same relative measurements in smaller specimens.

Locality.—Lower beds of Muddy Creek, near Hamilton, Western Victoria; clays of the Old Cement Works, Balcombe's Bay, Mornington.—Balcombian.—Eocene.

Astele millegranosa, sp. nov. (Pl. XIX., Figs. 7, 8).

Description.—Shell trochiform, rather thin and fragile, composed of eight or nine spire-whorls and about one and a half smooth embryonic whorls.

Spire-whorls usually flattened, but occasionally slightly concave in the earlier portion of the spire, in which case the aspect of the shell is somewhat altered in the direction of giving a broader and more squat form. Spire-whorls bearing fine spiral threads increasing from about three to eleven or twelve on the body-whorl, the basal thread of each whorl being the strongest, forms a well-marked girdle, the remaining threads varying in strength; each thread is furnished with a fine beaded ornament, the size of the beads varying with the strength of the threads, the interspaces between the threads bearing fine oblique striae of growth. The ornament on the earlier spire-whorls is beautifully fine, and has a distinctly clathrate appearance owing to the spiral threads being crossed transversely by slightly oblique striae, with only slight noding for the first three or four whorls; then the noding strengthens and develops into beads, and finally

tends towards spiny elevations on the spiral threads under the lens. The granose ornament tends to become obsolete on the flattened (in young specimens), to slightly convex base (in adult specimeus), but the young shells show several of the spiral threads in the neighbourhood of the umbilicus with a fine beaded sculpture. The base of the adult shows about fourteen or fifteen spiral threads, somewhat unequal, with an occasional fine intercalated thread near the periphery; this spiral sculpture is crossed by sigmoidal lines of growth radiating from the umbilicus. Base furnished with a wide and very profound umbilicus extending nearly up to the embryonic whorls; margin of umbilicus furnished with a comparatively broad crenulated band, while the whole interior bears beaded spiral threads of unequal strength. Aperture quadrate, outer lip and inner lip both thin and slightly crenulate in conformity with the spiral threads.

Dimensions.—Height, 23 mm.; greatest diameter, 29 mm.; height of aperture, 7 mm.; breadth of aperture, 9 mm.; diameter of umbilicus from margin to posterior of aperture, 9 mm. More erect young forms, height, 18 mm.; diameter at the base, 19 mm.; also 12 mm. by 10.5 mm.; 10 mm. by 10 mm., and 8 mm. by 8 mm.

Locality.—Lower beads of Muddy Creek, near Hamilton, Western Victoria.—Balcombian.—Eocene.

Observations.—This is apparently the forerunner of our living Astele subcarinata, Swainson, but it may be very readily separated, and it may also be noted that it is the squat adult form which appears to develop the greatest affinity.

Eutrochus fontinalis, sp. nov. (Pl. XIX., Fig. 9).

Description.—This, though a smaller shell, is closely related in many of its characters to the foregoing species, but differs in its more slender form, its fewer and less regular spiral threads, slightly coarser ornament, narrower and more circular base bearing broader flattened spiral bands with obscure beading, comparatively narrow and shallow umbilicus margined by at least three distinct beaded spirals, and robust columella.

Dimensions.—Height, 15 mm.; diameter of base, 13 mm., height of aperture, 4 mm.; breadth of aperture, 5 mm.: diameter of umbilicus barely 2 mm. Smaller specimens down to height 6 mm., diameter of base 5 mm.

Locality.—Lower beds of Spring Creek series or Bird Rock Bluff, near Geelong.—Jan Jukian.—Eocene.

Observations.—The most striking features to distinguish this form from the foregoing are in the umbilical characters, which do not admit of any hesitation in making the separation.

Bankivia howitti, sp. nov. (Pl. XVIII., Fig. 1).

Description.—Shell large, subulate, with a rather broad base, and consisting of about six smooth, flattened spire-whorls, and about two depressed embryonic whorls of a somewhat convex aspect. The shell, though rapidly tapering as a whole, is somewhat blunted at the apex by the depression of the small embryonic whorls; the general apical angle ranges from thirty to forty degrees, but the taper is not uniform, the spire taper averaging thirty to thirty-five degrees, but near the apex it falls away much more rapidly.

Whorls flat and only showing oblique lines of growth, except the body-whorl which shows faint spiral lines increasing in strength and number towards the base, about ten or twelve fairly strong spiral ridges showing at the base, suture slightly impressed, the later whorls developing a comparatively broad and strong sutural band, being on the penultimate whorl about one-fifth the height of the whorl. Aperture subovate, outer lip thin; columella short, twisted, and truncated at the base.

Dimensions.—Type, length, 27 mm.; greatest breadth, 12 mm.; height of aperture, 9 mm.; breadth of aperture, 5 mm. Smaller examples down to length, 19 mm.; breadth, 9; and length, 15 mm.; breadth, 7 mm.

An extra fine and large specimen is in the National Museum collection, Melbourne, and was presented by Mr. A. W. Howitt, and the dimensions of it have been kindly given to me by Mr. F. Chapman, as—length, 35 mm.; greatest breadth, 13.5 mm.; width of aperture, 6 mm.

Locality.—Sandy clays of Jimmy's Point, Gippsland.—Kalimnan.—Miocene.

Observations.—This species can at once be distinguished from our living B. fasciata by its more robust habit and striking sutural band amongst other features. It affords me much pleasure to name this species after Mr. A. W. Howitt, by whom it was collected many years ago during the carrying out of his

geological work in Gippsland, and several specimens of this species were presented by him to the National Museum collection, Melbourne. This species has appeared in some of our local lists of fossils under the manuscript name of Bankivia maxima, and attributed to Tate as author, but the above name will now replace it.

Pleurotoma murrayana, sp. nov. (Pl. XIX., Fig. 10).

Description.—Shell small to medium size with a rather blunt apex, slender elongate spire, and a body-whorl shorter than the spire.

Embryo consisting of about two whorls and a half, blunt apically, smooth and inclined to be angled medially after about the first half-turn; this portion is also rather more tumid and protrudes over the remainder of the embryonic whorls, spire whorls seven, rather flat to slightly convex between the channelled sutures owing to the marked overlap of the whorls. Whorls strongly nodosely keeled about the middle of each whorl and forming a well-marked shoulder on the body-whorl, also bearing spiral threads, usually two well-developed ones below the keel on each spire whorl with finer intercalated threads, and fine threads above the keel on the slope of the posterior suture. The body-whorl shows four strong spiral threads on the anterior slope in front of the keel, with finer threads of two degrees in the interspaces, and thence to the end of the snout spirally striate. The spiral sculpture is crossed by striae and undulations parallel to the lines of growth giving rise to a clathrate appearance on the slope towards the posterior suture. The keel marks the position of the sinus and is very regularly and acutely nodulose, nodules about eighteen to twenty on the penultimate and body-whorls. Aperture ovate, extending into a comparatively broad, straight canal of only moderate length. Outer lip thin and sharp, with a broad, deep sinus at the shoulder, thence ascending with a fair overlap on the penultimate whorl. Columella smooth, straight, and rapidly tapering.

Dimensions.—Length, 28 mm.; breadth of penultimate-whorl, 8 mm.; breadth of body-whorl, 9 mm.; length of aperture and canal, 12 mm.; breadth of aperture, 3 mm. Smaller specimens of length, 21 mm.; breadth, 7 mm.

Locality.—River Murray Cliffs, near Morgan.—Barwonian.—Eocene.

Pleurotoma granti, sp. nov. (Pl. XIX., Fig. 3).

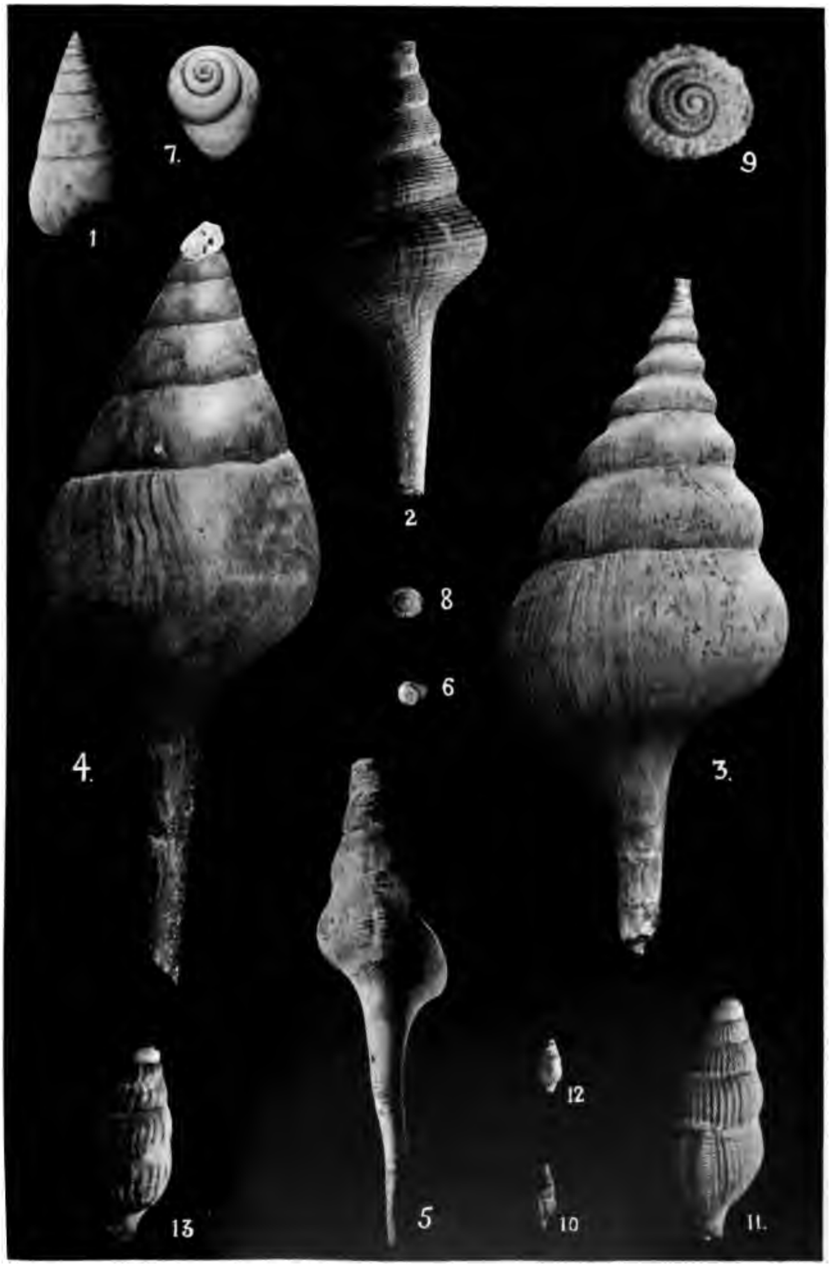
Description.—Shell large, very graceful and elongate fusiform; with a slender tapering spire less than half the total length of the shell, and a long straight canal.

Spire very acute, the general apical angle being only about twenty-two or twenty-three degrees, extreme apex bluntly rounded. Embryo composed of about two and a half smooth, slightly convex whorls. The remainder of the shell is composed of nine regularly convex whorls, greatest convexity about the middle of each whorl, suture impressed, but as the whorls distinctly overlap the greatest impression or concavity is a little below the suture. Whorls spirally lirate and striate, three or four threads usually being more strongly developed than the rest about the middle of each whorl, seven or eight threads being more thoroughly visible on the body-whorl, the remainder of the surface of the shell being very finely and regularly spirally striate. Transverse striae of growth usually very faint on the spire whorls, a little more distinct on the body-whorl, but distinctly subordinate to the spiral sculpture. Sinus broad and deep, and situated in the concavity between the suture and greatest convexity of the whorls, but nearer to the former. Aperture elongate-oval, extending into a long, straight, and comparatively broad canal; outer lip thin; inner lip well defined by a thin layer of enamel spread out over the columella and strongly margined off from the spiral sculpture, the margin extending down the full length of the long, straight, tapering columella.

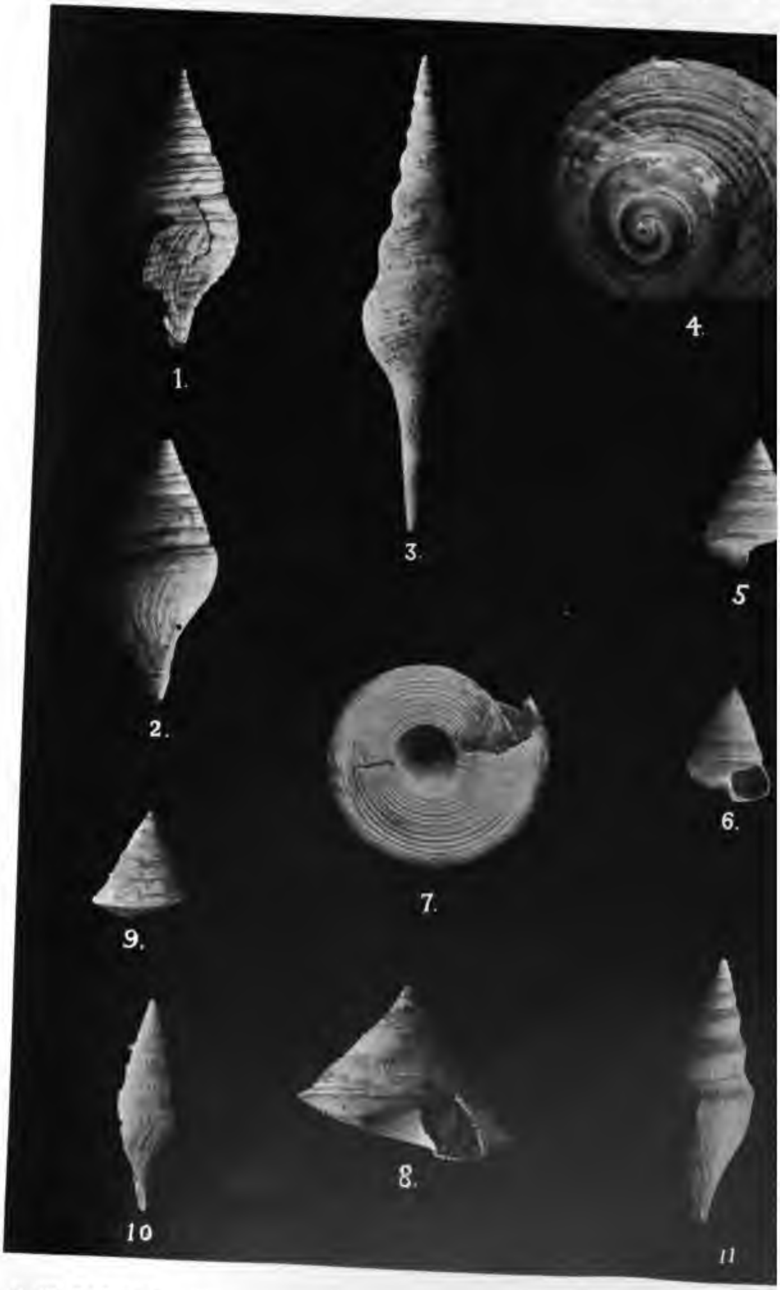
Dimensions.—Length, 63 mm.; breadth, 13 mm.; length of aperture and canal, 31 mm.; length of aperture, about 12 mm.; breadth of aperture, about 5 mm.

Locality.—Lower beds of Muddy Creek, near Hamilton. Western Victoria.—Balcombian.—Eocene.

Observations.—I have much pleasure in naming this graceful shell after my friend, Mr. F. E. Grant, who has done a considerable amount of work on our Tertiaries, and is always ready and willing to help others in their work in any way he can.



D. W. PATERSON, Photo.



D. W. PATERSON, Photo.

EXPLANATION OF PLATES.

PLATE XVIII.

Fig. 1.—Bankivia howitti, sp. nov. Natural size.
,, 2.—Clavella bulbodes, Tate. Young specimen, natural size.
,, 3.—Clavella bulbodes, Tate. Adult specimen, about one-half natural size.
,, 4.—Clavella platystropha, sp. nov. Adult specimen, about one-half natural size.
,, 5.—Clavella platystropha, sp. nov. Young specimen, natural size.
,, 6.—Collonia otwayensis, sp. nov. Natural size.
,, 7.—Collonia otwayensis, sp. nov. Enlarged about four diameters.
,, 8.—Collonia geelongensis, sp. nov. Natural size.
,, 9.—Collonia geelongensis, sp. nov. Enlarged about four diameters.
,, 10.—Columbella balcombensis, sp. nov. Natural size.
,, 11.—Columbella balcombensis, sp. nov. Enlarged.
,, 12.—Columbella approximans, sp. nov. Natural size.
,, 13.—Columbella approximans, sp. nov. Enlarged.

PLATE XIX.

Fig. 1.—Pleurotoma selwyni, sp. nov.
,, 2.—Pleurotoma selwyni, var. laevis, var. nov.
,, 3.—Pleurotoma granti, sp. nov.
,, 4.—Turbo hamiltonensis, sp. nov.
,, 5.—Cantharidus serratulus, sp. nov. With spiral threads of unequal strength.
,, 6.—Cantharidus serratulus, sp. nov.
,, 7.—Astele millegranosa, sp. nov. Umbilical aspect.
,, 8.—Astele millegranosa, sp. nov. Front view.
,, 9.—Eutrochus fontinalis, sp. nov.
,, 10.—Pleurtoma murrayana, sp. nov.
,, 11.—Apiotoma bassi, sp. nov.

All the figures on the above plate are natural size.

ART. XI.—*On Some New Species of Victorian Mollusca, No. 7.*

BY G. B. PRITCHARD AND J. H. GATLIFF.

(With Plate XX.).

[Read 14th July, 1904].

The present paper includes the descriptions of two new species which have been obtained along the coast-line between Rye, Port Phillip, and the Back Beach, Point Nepean. We also give figures of the new species, and for the photography and reproduction of these we have to thank Mr. D. W. Paterson. The species dealt with are as follows:

Tellina kenyoniana, sp. nov.
Cyclopecten nepeanensis, sp. nov.

Cyclopecten nepeanensis, sp. nov.

Description.—Shell very minute, white, thin and translucent, comparatively dull externally, but shining rather strongly internally. To the naked eye the shell is slightly oblique, convex, and nearly orbicular, and owing to its minuteness and delicacy no sculpture is ordinarily visible, but in strong sunlight an extremely delicate radial and concentric sculpture is just discernible. Under a pocket lens the umbos are acute and prominent, hinge line straight, and falling very little short of the full length of the valve, auricles relatively large and subequal, with radiating and concentric sculpture, the former being much the stronger. The whole surface of the shell shows a delicate tesselation due to the regular radial and concentric threads, the radial threads numbering from about fifteen at the middle of the valve to about thirty at the ventral margin, intermediate threads making their appearance as the valve grows; the concentric threads number from about fifteen to twenty.

Dimensions.—Length, 1.5 to 2.5 mm.; height, 1.5 to 2.5 mm.

Locality.—Back Beach, Point Nepean.

D. W. PATERSON, Photo.

Observations.—Three species of this genus have already been been described from Australia: C. murrayi, Smith, in the Challenger Report, and C. favus, Hedley, and C. obliquus, Hedley, in the Memoirs of the Australian Museum. Our species, though closely related in many respects to the above, yet appears to be quite distinct from any of them. We have submitted specimens to Mr. Hedley, and he has kindly compared them with the types as those named by him, and he considers that ours is different.

Tellina kenyoniana, sp. nov.

Description.—Shell oblong, oval, somewhat solid, inequivalve, almost equilateral, somewhat tumid, posterior side slightly longer and narrower than the anterior, both valves are densely concentrically striated, the striae occasionally anastomise, and at the ventral margin and each end, become erect and sharp, and under the lens, these striae are finely transversely striated on their lower side. The ventral edge is, under the lens, very finely and densely transversely striate. The ligament is large and prominent. Colour white, with a clouding of reddish-yellow in the umbonal region; with about nine, narrow, somewhat indistinct. rays, of the same colour, extending from thence to the ventral margin; inside tinted with pale purple. Pallial sinus relatively small.

Dimensions.—Antero-posterior diameter, 61 mm. Umbo-ventral diameter, 35 mm.

Locality of type.—Airey's Inlet; odd valves found on beach at Portsea and Rye.

Explanation of Plate XX.

Fig. 1.—Tellina kenyoniana, sp. nov., exterior of left valve. Natural size.

,, 2.—Tellina kenyoniana, sp. nov., exterior of right valve. Natural size.

,, 3.—Tellina kenyoniana, sp. nov., interior of left valve. Natural size.

,, 4.—Tellina kenyoniana, sp. nov., interior of right valve. Natural size.

,, 5.—Cyclopecten nepeanensis, sp. nov. Enlarged 4 diameters.

END OF VOL. XVII., PART I.

[PUBLISHED SEPTEMBER, 1904.]

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CONTENTS OF VOLUME XVII., PT. II.

ART. XII.—*The Mount Morgan Gold Mine, Queensland.*

BY E. J. DUNN, F.G.S.

(With Plates XXI., XXII.).

[Read 11th August, 1904].

The writer visited this mine in 1889, when the Mount was almost in its original condition, in 1890 and again in 1894, and enjoyed exceptional opportunities of examining the upper and richer portion. The first survey of the mine and surroundings was made under his supervision in 1889. Several comprehensive reports on the mine have been published, of which Dr. Jack's three reports, issued by the Queensland Geological Survey in 1884, 1889 and 1892, are by far the most complete.

In 1887 J. Macdonald Cameron published a report on the mine, and since 1892 the Queensland Geological Survey has issued some short reports about the mine; but so far as the writer is aware no clear description of the structure of the mine, as disclosed to 1894, has been printed.

In 1894 the last remnants of the highly-enriched zone were removed, and the open workings at this time explained much that was previously obscure. The several examinations made by the writer were in the interests of clients, and therefore the data were not available for publication until some time had elapsed.

Dr. Jack's view was that a thermal spring had deposited the auriferous rock at Mt. Morgan. From this view Mr. Cameron dissented. The late Mr. Wesley Hall and the then mine manager (Mr. Lisle) held the view that the oxidization of sulphides accompanied by heat sufficient to melt the quartz even, and an inflow of water from below, caused a "chemical outburst," and the gold and other material was subsequently deposited (Cameron's Report).

Rocks.

From the base to the summit of Mt. Morgan, which attained a height of 580 feet above the Dee River, igneous rocks predominate, and these constitute the country rock within which is enclosed the large mass of siliceous material forming the ore body. South of Mundic Creek is a very extensive tract of course-grained hornblendic igneous rock of uniform character. Higher up the western slope of the Mount, where the Rip and Tear tunnels are, the rock appears to be a decomposed crystalline igneous rock. On the south side of the Mount beds of volcanic ejectamenta, including many fragments of red jasper, are exposed near the New Reduction Works. Further up the spur, and near the mouth of Freehold Tunnel, variolite occurs. On the east side of the Mount from Linda Creek upwards crystalline igneous rocks, such as diorite, syenite, etc., are exposed. On the north side of the Mount a considerable area is occupied by siliceous cavernous rock, from which sulphides have been removed. It is doubtful whether the rocks resembling quartzite met with in the tunnels, etc., are of ordinary sedimentary origin.

The top of the Mount was occupied by, first, a core of soft red sandstone horizontally laid down and much false-bedded, surrounded by beds of loose sand, highly coloured with iron oxides in part, and these again were surrounded by a belt of limonite and beds of sand rich in iron oxides partly stained black from the presence of manganese oxide. Almost entirely surrounding this belt were the siliceous skeleton rocks from which the sulphides had been removed (Tufa of Dr. Jack's reports). Outside this siliceous rock, and forming the walls of the mine, was an altered igneous rock completely kaolinised, but in which the crystals of felspar were still clearly discernible. This rock appears to be an altered diorite. Cutting through the siliceous skeleton rock, and also through the diorite walls of the mine are dykes that also appear to have been originally of diorite, but that are completely kaolinised at the surface.

These dykes do not penetrate the loose sandy beds or the limonite of the secondary ore, nor do they cut through the [1]Desert Sandstone core, for this is of still later age.

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1 Later research renders it improbable that these beds are of Desert Sandstone age.

In the deeper levels of the mine the walls are in an unaltered condition, and appear to be of fine grained diorite. In one case such rock was thickly studded with scales of native copper.

Up to the present no microscopical examination of the extremely interesting group of rocks around Mt. Morgan appears to have been made.

STRUCTURE.

As shown on the accompanying plan and section, the top of Mt. Morgan is occupied by a plug three-fifths of an acre in extent of sandstone (A). This sandstone was evidently an outlier from the Desert Sandstone of Dr. Jack, which is so well represented a few chains to the north-west, capping the range. The plug was doubtless at one time continuous with the main mass, and its isolation was due to denuding agencies which have also pared it down to the condition it was in before removal by mining operations. The sandstone was moderately coarse-grained, red in colour at the surface, but nearly white in parts lower down. It was bedded horizontally in beds from a few inches to a couple of feet thick, and extensively false bedded. The mass formed an inverted flattened cone, and filled the inside of the funnel-shaped mass of sandy beds of secondary ore (B on plan and section). Assays of this sandstone gave up to 3dwt. of gold per ton, and this is not remarkable, seeing that the walls of the cavity in which it was laid down were highly auriferous. The whole of this plug, which was nearly 100 feet deep at its thickest part, was quarried and tipped over the side of the Mount, so as to remove the rich secondary ore below it. It was quite distinct from, and unconformable to, the beds of loose sand, etc., underlying it. By means of this outlier of desert sandstone it is clearly established that the secondary ore was laid down before the Desert Sandstone began to be deposited, though probably not long before. From the degraded condition of the plug it is certain that denudation had removed a portion of the secondary ore around the plug, but there was not any means of gauging the extent of this work. Formerly a blacksmith's shop stood on the plug of sandstone.

Surrounding the plug of sandstone were beds of loose sand, etc., very irregularly bedded and disposed somewhat after the form of a rim of a funnel (B on plan). Towards the centre the

material was less ferruginous than towards the outside of the area, where highly ferruginous beds and belts of limonite were prominent.

A ferruginous belt (C) extended outside of the beds above described (B), and continued downwards to what would be called the stem of a funnel to a depth of 150 feet from the surface. Much of this ironstone was extremely hard, and Krom rollers were used to crush it. Much of it was extremely rich in gold, which was disseminated through the stone in microscopic particles, but which was occasionally visible to the unaided eye. Assays of hundreds of ounces of gold per ton were obtained from this class of ore.

This secondary ore formed a zone of enrichment, and the whole of the material from the central plug of sandstone to the rim of cellular siliceous rock was payably auriferous. The bulk yielded several ounces of gold per ton. and portions assayed for hundreds of ounces per ton.

Between the ferruginous zone (C) and the leached cellular siliceous ore (E) there was usually a band of sand or soft bed (D) from a few inches to many feet thick; this appeared to be present wherever the floor was moderately inclined, but was absent where the floor of siliceous ore was steeply inclined. This band of loose material was in places extremely rich in gold.

Underlying, and almost surrounding the whole of the above secondary ores, is a great mass of siliceous and kaolin ore (E), representing the upper and oxidised portion of the siliceous sulphide ore met with deeper in the mine. The friable silica is cellular from the removal of the pyrites; a great deal of this in the mine is white, showing how thoroughly it has been leached, but in places the stone was very ferruginous, and in some places a little of the sulphide still remained unaltered. At the surface this stone was generally stained nearly black with manganese oxide. Nodules, with unaltered pyrites, were met with even at the surface. Very large quantities of this ore have been mined for gold at the surface and underground, but a great deal of it is not sufficiently rich in gold to be profitably worked. At the surface there is an extensive area to the north-west of the shaft that is not mined much past the flagstaff, as its gold contents is too low. Kaolin ore occurs extensively developed in this oxidised or impoverished zone. Gold occurs in a most

irregular manner distributed through the siliceous and kaolin ore. The average contents of gold in this zone would probably be only dwts. against ounces in the enriched zone.

The oxidisation and leaching of this ore has extended from 180 feet from the surface to perhaps 300 feet in the deepest part, and, as elsewhere, this action has prevailed less deeply along the walls than towards the centre of the mass of ore. There can be little doubt that so fas as leaching has proceeded gold has been conveyed thence in solution and again deposited in the enriched zone, and although the sulphides in their original condition in the upper portion of the mine may have been in no richer gold ore than in the lower portion now being worked, the extensive concentration from an enormous bulk of adjacent ore might account for the wonderful accumulation of gold in the enriched zone or secondary ore.

Formerly the term tufa was applied to the cellular siliceous ore of this zone, and certainly its appearance in the upper workings was unusual, but now that it has been followed down to its roots there is no room for doubting that it is merely the skeleton of silica, the sulphides having been oxidised and leached out.

Everywhere in the mine as depth is attained this oxidised and leached ore is found to give place to sulphide ore, (F) the unaltered zone. The change is gradual in places, and first iron pyrites is met with, then at lower depths copper pyrites is met with associated with the iron pyrites. In the sulphide ores gold is most irregularly distributed, and in the bottom levels the average gold contents has fallen to as low as $1\frac{1}{2}$ dwts. of gold per ton, but the copper contents have increased. In this connection bulk, as against weight, has to be considered, for a ton of sulphide ore would perhaps be only 10 or 11 cubic feet, while a ton of the cellular siliceous ore would probably exceed 30 cubic feet, so that until careful experiments are made as to the proportion of gold per cubic yard in the different portions of the mine it would be unsafe to assume that there is an actual diminution in the gold contents in the original ore as depth is attained.

Then outside the sulphide ore and skeleton ore from which the sulphides have been removed are the walls of crystalline igneous rocks (G), altered at the surface to kaolin, but in the deeper levels unaltered and apparently diorite, etc.; also a

similar class of rocks altered to kaolin at the surface, but little altered in depth, which cut through G, F and E as dykes (H). These dykes are clearly of later date than the massive igneous rocks (G), but they are older than, and do not intersect A, B, C, or D. They formed a conspicuous feature on the surface of the mine, ranging from 25 feet in thickness down to mere threads.

Gold-bearing Ores.

Enclosed within boundaries formed of igneous rocks is a great body of quartz of irregular form, and covering many acres at the surface. In depth the quartz is thickly impregnated with sulphides. At the surface, and for a considerable depth below, the sulphides have been decomposed and removed, leaving the siliceous skeleton. This surface rock of siliceous composition and cellular structure was described by Dr. Jack as sinter, but further workings have fully established the fact that the cavernous siliceous rock at the surface is continuous with the upper portion of the quartz and sulphide ore met with in the deeper levels of the mine. Even at the surface odd nodules of ore were met with in the siliceous rock containing unaltered pyyites.

This siliceous sulphide body is undoubtedly the original source from which all the Mt. Morgan gold has been derived.

At the lowest depth attained in the mine, some 850 feet from the summit of the Mount, the ore is a dark-grey, finely-saccharoidal quartz, thickly studded with iron and copper pyrites, the former greatly predominating. This ore carries from 2½ to 3½ per cent. copper and from 1½ dwt. to 8 dwt. of gold per ton. It is noteworthy that some of the iron pyrites is in dodecahedral crystals. In the Pilgrims' Rest Goldfields, S. Africa it was observed that the iron pyrites of pentagonal dodecahedral form was rich in gold, while the cubical crystals were barren.

A prominent feature of this mine is the increase of copper sulphides in depth. Stains of copper were noticeable even at the surface, showing that copper sulphides existed there formerly, and the explanation probably is that the copper sulphides, being more readily oxidised and removed in solution, have dis-

appeared even below where the iron sulphides still survive, but that a zone has now been reached where the ores are in the condition as originally deposited. From an industrial point of view, this change in the character of the ore is serious; for, whereas the ores first worked were for gold only, the future development of the mine must be as a copper and gold proposition, the copper greatly outweighing the gold in importance. Eventually it is likely that the mine may become a copper mine, the gold being merely a by-product. Necessarily following this change in the nature of the ore is an entire alteration in the plant and methods involving heavy expenditure.

Origin.

As to the origin of this great body of siliceous and sulphide ore, there is some obscurity. Its great mass and its relations to the surrounding igneous rocks differentiate it from ordinary lodes. Besides, at the Sugar Loaf another similar body of ore exists also with similar surroundings, and still others in the neighbourhood. Whether it resulted from igneous agency or not has yet to be worked out, but the intimate manner in which similar cavernous siliceous material was blended with the felspathic material at the archway that formerly stood at No. 3 level as observed by the writer seemed to point this way.

Dykes of various dimensions cut through the siliceous sulphides in many places, and the rock is not as altered as at higher levels.

In the upper levels, besides the friable siliceous material, very extensive bodies of kaolin ore were also met with and extensively mined. Although the kaolin ore in some cases was undoubtedly produced from the decomposition of dykes of felspathic rock that were not necessarily auriferous originally, but that may have become so through the decomposition of the auriferous sulphides in the siliceous ore around them, and the gold derived from the pyrites in solution may have been redeposited in the kaolin, it is not certain that all the kaolin could be thus accounted for. In some parts the ore itself appears to carry much kaolin, but this point will be far clearer in the lower levels now being opened out.

In No. 5 tunnel, east end, dyke material now kaolinised ramifies through the siliceous ore as under:—

Of still greater interest than the sulphide ore and the skeleton ore, from which the sulphides have been removed, is the secondary ore. It is of most unusual character, and the writer has not met with anything similar elsewhere. The distinction between this ore and the cellular, siliceous ore surrounding it appears not to have been sufficiently emphasised, and this has probably led to some confusion. In the earlier stages of the mine the relation of this ore to its surroundings was obscure, but the further operations that resulted in the removal of the whole of it, and also of the plug of sandstone in its centre by open cast workings, disclosed these relations in a very distinct manner.

Roughly, the secondary ore of Mt. Morgan was funnel-shaped. It was surrounded at the surface by the cellular siliceous ore on the north and west sides, and by kaolinised igneous rock on the south and east sides. In outline it was of irregular oval form and covered, with the plug of sandstone in its centre, an area of about $2\frac{1}{2}$ acres on the top of the Mount. The extreme summit of the Mount was just west of the edge of this area. Everywhere this ore covered the cellular siliceous ore, and to a depth of 50 or 60 feet, but extended to a depth of 160 feet

from the surface in the deepest part. Within this area the material consisted of fine and coarse siliceous sand, some of the beds so incoherent that the sand ran freely; other beds were more clayey. The beds were highly inclined, very irregular in extent and varied much in thickness within short distances; but were less inclined, though still very irregular in the north-west portion of the area.

Some of these beds of sand were of light grey colour, but most were stained with oxide of iron, and towards the outer edge the beds were of brilliant reds, yellows, purple, and nearly black in some cases from a high percentage of iron and manganese oxides. In section, some of these beds were fan-shaped, as observed by Dr. Jack. A highly-ferruginous belt formed the outer margin of the area, represented in places by bands of limonite that attained a thickness of twenty feet in places. The greatest development of limonite was just north of the shaft. In the south-east portion of the area limonite was also strongly represented. The limonite was of light brown colour, very hard, and contained grains of quartz scattered through the mass. Before the surface was cut up by mining the area occupied by secondary ore was plainly defined by a distinct, and in places very strong, outcrop of ferruginous material. Limonite formed a conspicuous feature at the surface, projecting 10 or 12 feet above the ground in places. It did not occur in a solid vein, but in irregular more or less spherical blocks with botryoidal or stalactitic surface, and up to a ton in weight. Some of the limonite was light and frothy, stained black from manganese oxide, or most brilliantly iridescent. Generally there was a selvage of sandy material resting directly on the cellular siliceous ore, then the limonite. This selvage ranged from a few inches to many feet in thickness. In places this sand was spangled with fine particles of scaly gold. Where the portion corresponding to the stem of the funnel was it consisted of blocks of limonite bedded in red clay. It was the marvellous richness of this secondary ore that established the fame of Mt. Morgan, and that supplied many millions' worth of gold within a few years. Morgan's first trench was in this class of ore. Immense quantities of ore from this portion of the mine gave 8 to 10 ozs. of gold per ton. Some of the sandy beds yielded up to hundreds of ounces per ton. The

richest spot was about 20 feet north-west from the shaft on No. 3 floor. The limonite also in places was phenomenally rich in gold; some large blocks assayed up to 800 ozs. per ton. Taken as a whole, the secondary ore was a marvellously rich deposit of gold-bearing material. It represented a zone of enrichment, and the gold it contained was derived by the leaching and impoverishment of an enormous mass of adjacent ore.

When the great richness of the surface ore at the Mount was proved, prospecting was eagerly pushed on with the object of discovering the continuation in depth, but although the Mount was pierced right through at several points and right beneath where the rich ore stood, no continuation could be discovered below, and the reason is obvious from the plan and section given. For while the workings at the surface were in the enriched zone of secondary ore the tunnels were driven through the impoverished zone of cellular siliceous rock from which the sulphides and much of the gold had been leached out.

The secondary ore was, with the exception of the ironstone, in such a loose and friable condition that most of it was removed with a shovel.

It is quite possible that in the secondary ore a certain amount of Desert Sandstone material may have been mingled with the material resulting from the disintegration of the cellular siliceous rock, for the Desert Sandstone sea must have covered this area while the secondary ore was being formed, and that some sand should have been carried in seems quite natural.

Gold.

In the enriched zone gold existed not only in exceptional abundance, but the quality was abnormally high; in fact, no naturally-formed gold is known that more nearly reached chemical purity than the gold obtained near the surface at Mt. Morgan. Thousands of ounces were bought at the Sydney Mint that were 99.7 fine, and some reached 99.8. This unusual degree of fineness was certainly due to the processes by which the much-alloyed gold of the sulphides was first dissolved and leached out of its original ore and then re-deposited under such conditions that no silver was deposited at the same time.

Such pure gold was confined to the secondary ores of the enriched zone. The siliceous and kaolin ores of the impoverished zone carried a considerable percentage of silver alloy, amounting to 43 per cent. in some cases, and as the gold in the secondary ores was furnished from the ore that yields bullion with much silver, it is evident that the silver has been got rid of in its transference from the leached ore to the enriched zone.

Lower still in the mine the gold of the sulphide zone is much alloyed with silver.

A characteristic of the gold at Mt. Morgan was its extreme state of subdivision. This was so much the case that some examples carrying scores of ounces of gold to the ton showed nothing that could be detected by the naked eye, even in some cases ore carrying over 50 ozs. per ton disclosed no visible gold. In the trench sunk by Morgan where the stone was fabulously rich the gold was excessively minute. It was visible in the ironstone in places as small crystalline flakes and also as loose crystalline spangles thickly disseminated in some of the beds of loose sand. Before Mt. Morgan was discovered alluvial gold was worked in Linda Creek.

The extremely fine character of the gold at first proved an impediment to its extraction, as it could not be recovered by the ordinary battery and amalgamation. Assays of the tailings showed that but a fraction was being recovered. Chlorination was had recourse to, and solved the problem.

As much as £4 4s. 8d. per oz. was paid for the earlier parcels of gold from this mine.

Throughout the mine in the several classes of ore the distribution of the gold was most erratic, one assay would give but a trace; the next might give ounces per ton.

Of such great fineness were the particles of gold that the red dust which escaped from the dust chamber of the mill taken at a distance of a mile away, yielded assays of 1 oz. per ton, as the late Mr. Wesley Hall informed the writer.

In 1889 over a ton of gold per month was being despatched from the mine, and this continued for about a year.

It is curious that although the gold of this mine occurs associated with much copper in the form of sulphide, it does not appear to be alloyed with that metal, but with silver. The total

yield of gold to June, 1904, is about $111\frac{1}{2}$ tons; worth £11,150,087. Average value of the gold about £4 1s. $0\frac{3}{4}$d. per oz.

Geological History.

In considering the series of events that have combined to produce Mt. Morgan as it stood when mining operations began, the period preceding that at which the Desert Sandstone sea covered the Mount, will not be considered, as these antecedent events can be more accurately and easily followed when the lower workings are further developed.

At the time this sea encroached on the top of the Mount, there was a large area of siliceous ore bounded by igneous rocks, exposed at the surface, that had undergone some denudation, as proved by the position of the "overflow" of Dr. Jack, and this ore had no doubt become oxidized to a greater or less extent. Still, it is not probable that oxidization had penetrated to a very great depth. When the water from the sea spread over this ore with unaltered sulphides near the surface a violent set of reactions appears to have been set up in the area now occupied by the secondary ores.

Why this special area should have been the centre of so much activity is not apparent, unless it represents a portion of the ore mass more highly charged with sulphides than the rest, or with sulphides more easily oxidizable than in the surrounding mass. The effect of this action was to completely disintegrate the siliceous sulphide mass of ore, and to oxidise the sulphides and dissolve the gold and silver contained in the sulphides. Only a violent mechanical action, the result of fierce chemical reactions, could have torn this ore apart and reduced it to the condition of sand and argillaceus material, such as formed the secondary ore. The extremely irregular manner of the deposition also points out that the water it was laid down in was not by any means quiescent. All the materials found in the secondary ore beds are such as would be furnished by the siliceous sulphide ores; but the whole of the material supplied by the sulphide ore was not laid down again in the area in which the violent reactions took place. A great deal of it, in suspension as fine mud, was carried further away, and may now be seen at a lower level

on the sides of the Mount, covering the rocks and surface as exposed before the Desert Sandstone was laid down. This bulk of "overflow" should, roughly, represent the space left in the secondary ore, and subsequently filled in by a plug of Desert Sandstone, plus, perhaps, some of the material subsequently leached out from the sulphides at lower levels.

The sand of the secondary ore came from the siliceous component of the ore, the aluminous material from the kaolinised dykes, etc., and perhaps from portions of the ore either in the form of solution or suspensin, or both; the limonite was supplied by the decomposition of iron pyrites. As solvents of gold, supposing the waters were sea waters, there would be chlorine, bromine, iodine, etc.

When the more violent conditions ceased, the materials filling a basin shaped cavity began to re-arrange themselves, and first the heavy iron solutions and the coarse sandy particles were laid down, and with these much of the gold in solution was deposited, but not the silver; and this would imply that conditions prevailed favouring the deposition of gold, but not silver, from the solutions. In this way the gold was so completely parted that it approached chemical purity.

Although an area above described was subject to powerful action, by which the ore was completely disintegrated, the rest of the area of sulphide ore exposed to the same action was not disintegrated, but the sulphides were merely oxidised and leached away, leaving the siliceous skeleton standing at the surface; this was usually nearly black from manganese oxide.

Just as the disintegrated portion of the ore only extended on the surface over a certain area, so downwards the disintegration was also limited. The deepest point was about 150 feet from the surface, but over much of the area the depth was much less than this. So that beyond the limits of the disintegrating forces the chemical reactions appear to have been less active; perhaps they were slower, and possibly the sulphides were less plentiful or of a different composition.

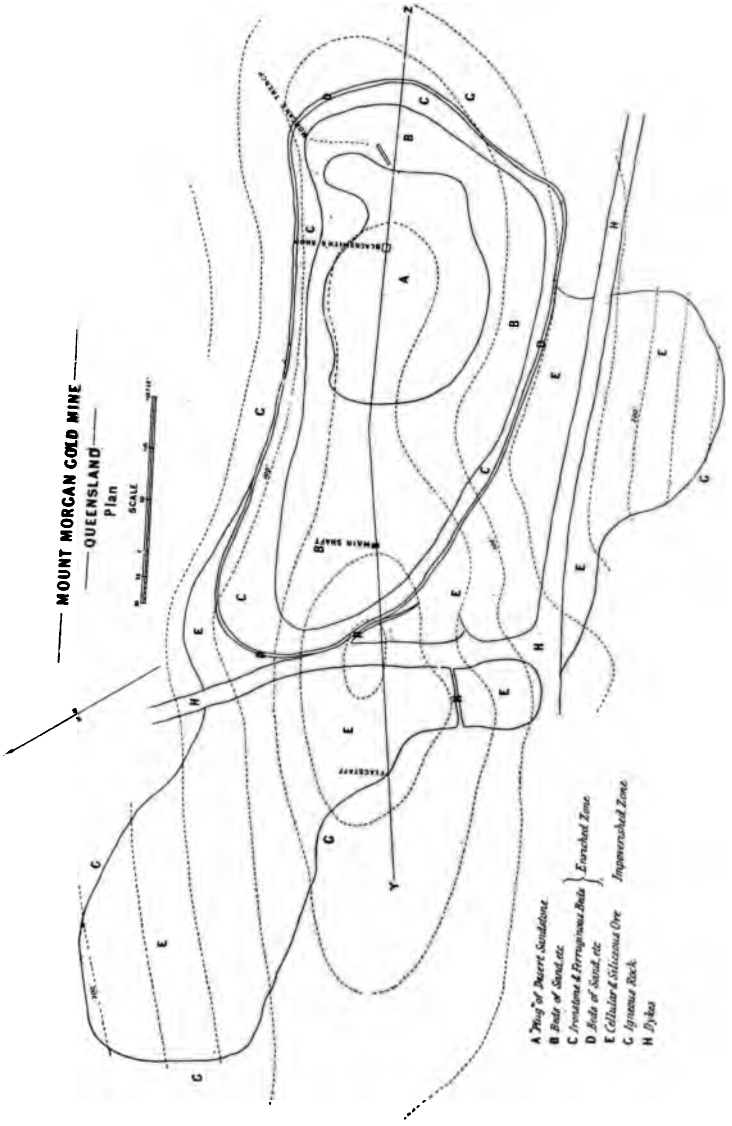
Still, oxidization and leaching of the sulphides continued long after the disintegrating forces ceased to act, and may have continued down even to the present time.

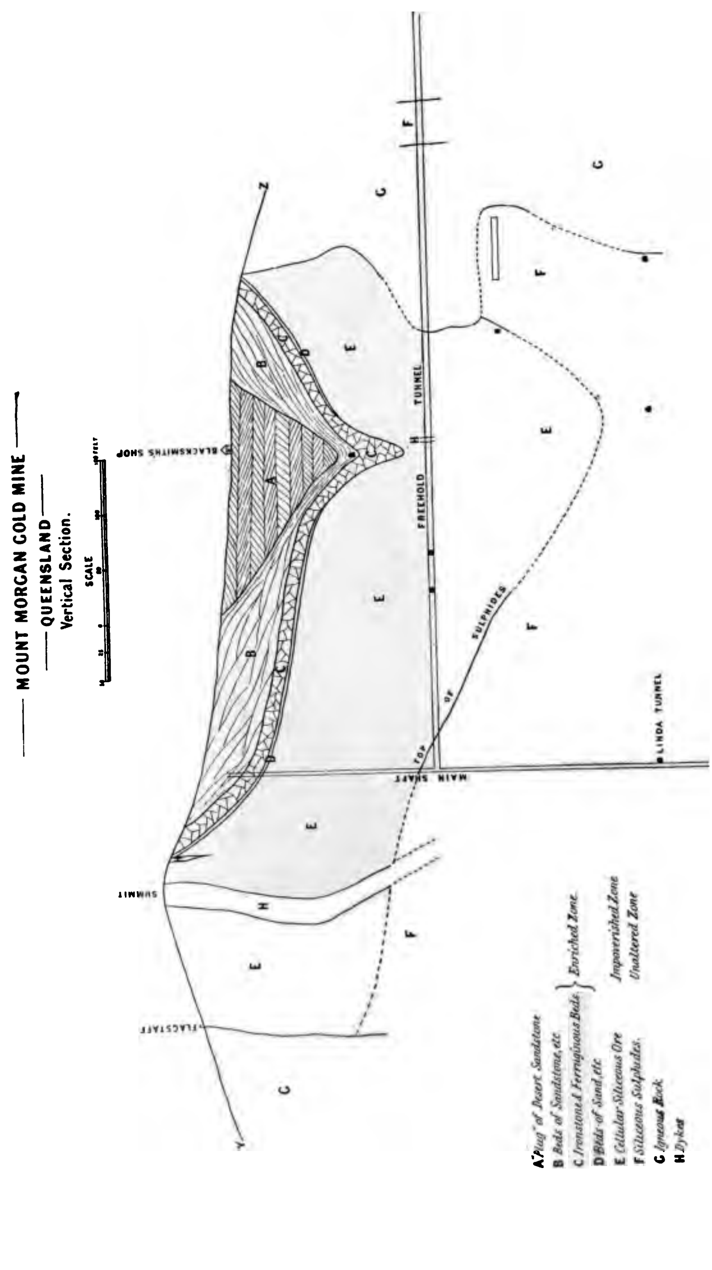
The action of sea water on the sulphide ore is held by the writer to sufficiently account for the phenomena of the secondary ores of Mt. Morgan without calling in the aid of thermal springs. Besides the thermal spring was meant by Dr. Jack to account for the origin of the siliceous skeleton of the sulphide ore which he then called sinter; but this skeleton has now been traced downwards, and proved to be the upper leached portion of siliceous sulphides.

It would not be necessary to invoke the aid of a thermal spring if sea water could accomplish the work, for it is certain that this spot was covered by the sea or a lake about the time when the violent disintegration was at work, for as soon as the sands and clays had re-settled in the basin, leaving a cavity in the centre where the activity lasted longest, then horizontal beds of Desert Sandstone were deposited, and these were piled up to a height of 100 feet or more within the centre of the basin, the ends of the beds resting on the sands, etc., of the secondary ores, and this accumulation went on until such horizontal but much false bedded sandstones were built up for perhaps hundreds of feet above the top of the Mount as presented when mining began. These accumulations of sediment went on until the conditions changed, and the sediments emerged from the sea and were exposed to the air. Since then extensive denudation has been at work, removing the cover of sandstone from a great area about Mt. Morgan, leaving the plug on the Mount itself because it was protected from wear and tear by being countersunk in the secondary ore. These denuding forces are still in full activity, carving the valleys deeper and lowering the summits and ridges.

It is probable that the actual disintegration and subsequent re-deposit of the secondary ore did not occupy any very long period; the very fierceness of the action would imply a rapid completion, and no doubt most of the gold from the ore disintegrated was thrown down again within the basin, but this would not account for all that was found there.

Some small proportion of the gold was certainly carried away in the slimes or "overflow," and assays of this "overflow" material were said to yield small assays of gold. But if a little thus escaped, it is probable that the secondary ores were


MOUNT MORGAN GOLD MINE
QUEENSLAND
Plan
SCALE
MAIN SHAFT
A "Plug" of Desert Sandstone
B Beds of Sand, etc.
C Ironstone & Ferruginous Beds
D Beds of Sand, etc.
E Cellular & Siliceous Ore
G Igneous Rock
H Dykes
Enriched Zone
Impoverished Zone


MOUNT MORGAN GOLD MINE
QUEENSLAND
Vertical Section.
SCALE
BLACKSMITHS SHOP
SUMMIT
FLAGSTAFF
MAIN SHAFT
FREEHOLD TUNNEL
LINDA TUNNEL
TOP OF SULPHIDES
A ? "Plug" of Desert Sandstone
B Beds of Sandstone, etc
C Ironstone & Ferruginous Beds
D Beds of Sand, etc
Enriched Zone.
E Cellular Siliceous Ore
Impoverished Zone
F Siliceous Sulphides.
Unaltered Zone
G Igneous Rock
H Dykes

enormously enriched from gold in solution leached out of the oxidised ores and re-deposited in the secondary ore. The gold in a very pure and crystalline state in the secondary ore would be one strong means of extracting the gold from any solutions carrying gold that came in contact with it; also the conditions prevailing in these beds of secondary ore were no doubt just those that would in other ways conduce to the deposition of whatever gold was in solutions passing through them.

The chemical reactions that were brought into play under such conditions as existed at Mt. Morgan when the sea or fresh or brackish water came into contact with the sulphides, must necessarily have been of a very complicated nature, and these would form a most interesting subject for some chemist to investigate. It would not only be of interest from a scientific point of view, but also from an economic point, for the question arises from the present position of this great mine whether it would be possible to imitate nature's processes in working the abundance of low-grade sulphides encountered in the depths of the Mount. Possibly some electrolytic method might prove even more effective than pyritic smelting, because fuel at Mt. Morgan will be an expensive item.

In conclusion, although the writer differs from Dr. Jack as to the causes that have produced Mt. Morgan as we know it, it is a pleasure to him to bear ample testimony to the faithful and accurate descriptions of the Mount supplied by Dr. Jack in his reports.

Specimens of the Mt. Morgan rocks and ores obtained by the writer are in the collection of the Mines Department of Victoria, at the Exhibition Building. To Mr. Richards, the General Manager, the author is indebted for samples of ore and the statistics used.

DESCRIPTION OF PLATES.

No. XXI.—Plan of Mt. Morgan Gold Mine, Queensland.

XXII.—Section through the same.

ART. XIII.—*A Description of Ommatocarcinus corioensis, Cresswell sp., from the Lower Tertiary of Victoria.*

BY T. S. HALL, M.A.,

University of Melbourne.

(With Plate XXIII.).

[Read 8th September, 1904].

During a recent visit to Port Campbell I gathered a number of specimens of a fossil crab which turned out to be the only described species found in our Tertiaries, and, as the original description is not very precise, and is not accompanied by a figure, I thought it as well to supply the deficiencies, as till I saw Mr. Cresswell's specimens I could not be certain of their specific identity.

Ommatocarcinus corioensis, Cresswell sp.

Gonoplax corioensis, Cresswell. Victorian Naturalist, vol. 3, 1886, p. 86.

Carapace, nearly twice as broad as long. Front almost straight, being but slightly hollowed on each side of a median convexity. Interocular region three-fourths the width of the front and equal to the length of the antero-lateral spine. The spine when resting on the merus of the chelate limb reaches to its own length from the distal end of the merus. Lateral edges of the carapace converging posteriorly, the postero-lateral angles rounded. Hind-edge as long as the distance of the transverse ridge from it. This strong transverse ridge runs across the whole width of the carapace, and is slightly bent backwards near its ends, where it forms a small rounded projection on the lateral edge at about the length of the antero-lateral spine behind its base. The ridge is about one-third of the length of the carapace from the anterior border, and parallel to it.

The cardiac area is triangular and slightly tumid. It is bounded anteriorly by a well-marked ridge, convex in front, situated about one-third of the length of the carapace from the posterior margin. The sides of the carapace are nearly vertical except in the posterior two-thirds; where viewed from above there is an outward steeply sloping area. This meets an acute ridge, which is parallel to the fore and aft curvature of the dorsal surface.

Anterior edge of the carapace finely and regularly granulate from the distal end of the spine to the orbit. Surface finely granulate in the hepatic region, the granules being coarsest in the antero-lateral angle, and becoming finer as they recede from that point. Outer third of the transverse ridge granulate. The postero-lateral margin with coarse irregular granules along its upper edge. Remainder of the carapace smooth.

Chelipedes nearly twice as long as the length of the transverse ridge of the carapace. Arm trigonal, its lower edge granular on its proximal half, with three small, acute, equi-distant spines on its distal half.

Wrist with a prominent spine on its inner side, a smaller one at the outer distal angle.

Hand flattened, widest at the base of the finger, where its width is about equal to three-quarters of the length of the mobile finger. A broad, shallow groove along its posterior third marks off a flattened ridge along the inner edge, which is finely granular. The upper edge is similarly granular.

Fingers much compressed, with small irregular teeth; a slightly larger one about the middle of the free finger fitting between two similar ones on the immobile finger.

The mera of the ambulatory limbs are expanded, those of the posterior ones specially so, the breadth being more than twice the thickness.

Eye stalks very long.

MEASUREMENTS.

1. Specimen from Curlewis (Rev. A. W. Cresswell)—Fig 1.

Length, from hind edge of orbit to posterior margin - - - - - -	26 mm.
Breadth, just behind antero-lateral spines	45 ,,
Posterior margin - - - - - -	32 ,,

2. Specimen from Port Campbell—Fig. 2.

Breadth of Carapace (as above) - -	35 mm.
Length of antero-lateral spine - -	5 „
Breadth of front - - - - - -	7 „
Length of meros of cheliped - - -	20 „ ?
Length of hand - - - - - -	30 „
Greatest breadth of hand - - -	5 „
Length of mobile finger - - - -	13 „

3. Specimen from Port Campbell—Fig. 4.

Hand, length - - - - - -	45 „
Length of 3rd ambulatory leg (imperfect)	50 „

Measurements taken from White's original figure of O. macgillivrayi in the way described above, for comparison.

Length - - - - - - - -	20 mm.
Breadth - - - - - - -	42 „
Posterior margin - - - - - -	32 „

Mr. Cresswell's description says that the eye-stalks are short. This would be so much at variance with the other characters of the fossil that attention was naturally directed to it. None of my specimens threw light on the point, and Mr. Cresswell could not find the specimen on which he founded the statement. However, he kindly broke one of the nodules in which his specimens are preserved, and very fortunately the greater part of an eye-stalk was displayed. It is broken off distally, but the part that remains reaches as far as the base of the antero-lateral spine, and I have figured it (Fig. 3). None of my specimens show the length of the ambulatory legs, but Mr. Cresswell says that the second pair is the longest, and that all four pairs end in a pointed toe. I have not been able to check these statements. One of my specimens, however, shows that the legs reach out beyond the end of the merus of the cheliped.

I may say that Mr. Cresswell's description, though not couched in strict scientific language, is quite intelligible, and enabled me to suspect the identity of my specimens before I had the opportunity of comparing them with his. He referred his species to the correct family, but the inaccessibility of the necessary literature prevented his recognition of the real genus.

Ommatocarcinus corioensis is very closely related to O. macgillivrayi, White,[1] occurring in Queensland and New Zealand. There are, however, differences in the form of the carapace. The antero-lateral spine is directed slightly backwards in the recent species, and runs out straight in the fossil. The carapace again in the fossil species is squarer and less attenuated behind than in O. macgillivrayi. The transverse ridge is further back in O. corioensis, and cuts the lateral margin at a point distant from the base of the spine by the length of the spine itself, while White's figure shows it running nearly to the base of the spine. The cardiac area in the fossil is much more tumid and strongly marked than is shown in White's figure.

There is again a striking difference in the length of the chelipeds in the fossil and the Queensland forms, but the New Zealand specimens, according to Miers,[2] have theirs much shorter than the Queensland examples, which are still available for comparison in the British Museum. White says that in the latter the chelipeds are two and a half times as long as the carapace, measuring it from spine to spine; these are adult males; while Miers gives the measurements as about equal for the New Zealand ones. In this respect the fossil is intermediate, the measurements being about as 5 is to 4. There is no spinule in the middle of the upper margin of the merus of the cheliped in the fossil, while it is present in the recent species; otherwise the distribution of granulations and small spines seems the same.

The specimens that I gathered were found in the cliff sections, extending for some miles on both sides of Port Campbell, which is about ten miles north-west of the well-known "Gellibrand" section. The beds are nearly horizontal, and can be traced for many miles along the coast, though in many places they are inaccessible owing to the precipitous nature of the cliffs. The sandy clays containing the crabs overlie the blue clays of the "Gellibrand" section which, near the Glenample homestead, plunge rather abruptly beneath them.

1 White in Macgillivray, "Narrative of the Voyage of the Rattlesnake," 1852 Appendix, p. 393, pl. 5, fig. 1, 1*a*.

2 Rep. "Challenger," Zoology, vol. 17, p. 248.

Mr. Cresswell found some of his specimens at Curlewis, about ten miles from Geelong, and also on the Western beach of Corio Bay. The former section was described by Mr. Pritchard and myself some years ago.

The beds are of Barwonian age, and are generally regarded as Eocene.

According to White, O. macgillivrayi occurs in shoal water on mud banks, and, judging from the condition of many of the specimens of the fossil I found at Port Campbell, the animals must have been entombed in their burrows. Other fossils are rather rare in the beds containing the crabs, and consist mainly of a few brachiopods and mud haunting spatangoids.

My thanks are due to the Rev. A. W. Cresswell, M.A., for kindly allowing me to examine his specimens and for lending me what I required for comparison and illustration; while Mr. S. H. Fulton has given me the results of his experience on several points.

EXPLANATION OF PLATE.

OMMATOCARCINUS CORIOENSIS, Cresswell sp.

Fig. 1.—Dorsal view of carapace. The antero-lateral spines are broken, and the front is embedded in hard matrix. From a nodule, Curlewis (Rev. A. W. Cresswell).

Fig. 2.—Dorsal view of another specimen to show the front, anterior margin and spine. The specimen is somewhat crushed, and the posterior third of the carapace is wanting. The carapace is slightly tilted backwards to bring the front into view. From Two-Mile Beach, Port Campbell.

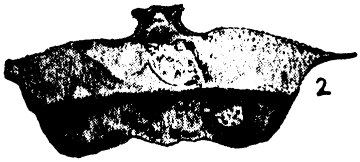
Fig. 3.—Another specimen showing the left eye-stalk which is broken. From a nodule, Curlewis (Rev. A. W. Cresswell).

Fig. 4.—Hand of another specimen. From Two-Mile Beach, Port Campbell. The original shows the ambulatory legs.

Fig. 5.—Wrist of another specimen showing spine. Two-Mile Beach, Port Campbell.

(All outlines drawn under the camera lucida. The figures are about natural size, except Fig. 5, which is enlarged about $2\frac{1}{2}$ diameter.)

1



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ART. XIV.—*Account of the Separation and Identification of a Kaolin Incrustation on Pyrolusite from Broken Hill.*

BY G. S. WALPOLE, B.Sc.

(Communicated by Professor Orme Masson).

(With Plate XXIV.).

[Read 13th October, 1904].

The specimen investigated was obtained by Professor Orme Masson from Broken Hill. It is bluish white externally, and consists, for the most part, of a lacework of rods and films. Parts of it are more solid and rather botryoidal in appearance. Any part that has been broken shows that the colour is due to a thin white film. Inside this the mineral appears to consist of black pyrolusite, enclosing occasional rounded grains of glassy quartz. No other mineral can be observed macroscopically.

THE MAIN PROBLEM WAS TO IDENTIFY THE INCRUSTATION OR FILM.

1. Several sections of the specimens were therefore prepared for microscopic examination. These were cut across the more solid parts of the mineral, and showed that the external layer is transparent and crystalline. No definite crystal shapes can be seen, but the mineral shows weak double refraction. The refractive index is very low. In the sections prepared, this mineral is always in direct contact with the pyrolusite, and even when it occurs very close to the other minerals is always separated from them by a thin film of pyrolusite. From a number of measurements made:—

Greatest thickness	-	-	.083 mm.
Least ,,	-	-	.024 ,,
Mean ,,	-	-	.054 ,,

2. The mineral, after powdering and passing through a fine wire sieve, was treated with hot concentrated hydrochloric acid, and it was found that ultimately everything dissolved except the incrustation and the quartz. Since the incrustation is a silicate, it was necessary, in order to determine its quantitative composition, to separate it from the quartz prior to analysis. The great difficulty experienced in this separation was due to the fact that the specific gravities of the two materials are very close together, being 2.61 and 2.65 respectively, the difference of specific gravity being the particular difference on which the methods of separation depended.

The first attempt at separation was made by use of a diffusion column using Sondstadt's[1] solution, of specific gravity 3.04, at the bottom of a tube covered by a diluted Sondstadt's solution of specific gravity slightly less than 2.6. Many modifications of the method were tried, but all failed to bring about any separation, as shown by examination of minute samples under the microscope.

The next method attempted was to shake up the mixed powder with Sondstadt's solution in a test tube and allow it to stand. Both minerals then rose to the surface. A single drop of water was then added, and the process repeated until at last a point was reached when the powder was divided into two layers, one of which sank and the other came to the surface. Samples of each layer were taken, and on examination each proved to be a mixture of the two minerals practically identical with the original mixture, both as to size of particles and as to proportionate quantities present. Several trials of this method always gave the same result.

The next step was to put this same solution with the suspended powder in the centrifuge. Two layers were obtained, the top one of which was poorer and the bottom one richer in quartz than the original mixture. The top layer was now stirred up without disturbing the bottom layer, and on again centrifuging more quartz left the top one. On repeating the operation three or four times the top layer was obtained quite

---

1 Sondstadt's solution. An extremely concentrated solution of Mercuric Iodide in aqueous Potassium Iodide solution.

free from quartz. To bring about a perfect separation it was found advisable to wash away from the powder the constituents of which are to be separated all the very fine particles so as to leave the grains about one size.

The result of the above experiments is to show that a separation of two constituents of the powder having specific gravities within .04 of each other, and having particles of maximum diameter .015 mm. is impossible by means of Sondstadt's solution useless the centrifuge be used as above described.

3. The isolated incrustation was examined. An analysis gave the following results:—

	Isolated Incrustation.	Calculated from formula $Al_2O_3\ 2H_2O\ 2SiO_2$	Analysis of Kaolinite given in Dana, quoted from Tookey & Dick, Percy's Metallurgy.
Al_2O_3	46.92	46.5	46.53
H_2O	14.09	14.0	13.87
SiO_2	38.99	39.5	38.93
	100.00	100.0	99.33

We see that the approximation of the composition of the material to that represented by the formula $Al_2O_3 . 2H_2O . 2SiO_2$ is very close.

The specific gravity was determined approximately in the following manner:—Some Sondstadt's solution was diluted down until it was seen that particles of the incrustation just floated. The specific gravity of the liquid was found to be 2.61 by Sprengel tube. Hence we may call this the specific gravity of the kaolin.

The account of the examination of the optical properties of the incrustation has already been given.

4. It was found, as a result of this investigation, that this incrustation is kaolinite.

Its percentage composition, specific gravity and optical properties under the microscope, together with the property of retaining its combined water at 150 deg. C., though parting with it at a red heat, agree with those given in Dana for kaolinite. Further, its properties under the microscope correspond with those of a known specimen of kaolinite mounted as a microscope slide for comparison.

NOTES ON THE REMAINDER OF THE MINERAL.

1. Microscopic Investigation.—Included in the pyrolusite is a colourless mineral generally occuring in aggregates of small crystals. Occasionally a single crystal section can be found. These sections are usually hexagonal in shape. One was isotropic, and the angle between its sides was 120 deg., so that the mineral would appear to belong to the hexagonal system. The crystals are too small to give a satisfactory interference figure with convergent polarised light. The refractive index is high, and the interference colours yellows and greys.

There is a third mineral present in minute quantities which can be easily picked out by its red colour. It gives no very satisfactory results in the slide, but can be obtained as separate crystals by powdering some of the original specimen, damping the powder, and then adding water. The red mineral is found floating on the surface. It is evidently not wetted by the water, and remains floating on account of the surface tension. It may also be separated on account of being the last mineral to dissolve on treating the powdered sample with concentrated hydrochloric acid. Examined under the microscope, it is seen to occur as well formed minute tabular crystals bounded by four rectangular sides. Some crystals are pleochroic and doubly refracting, and give a straight extinction. Others which are not isotropic remain dark between the crossed nicols, and give a uniaxial interference figure. The mineral is therefore tetragonal. It may be wulfenite ($PbMoO_4$).

Quartz also occurs throughout the pyrolusite in rounded grains of considerable size, which contain many liquid inclusions.

2. Chemical Investigation.—A bulk analysis of the specimen gave the following result:—

Insoluble in concentrated hydrochloric acid	Kaolin - -	4.14
	Quartz - -	5.22
Soluble in concentrated hydrochloric acid	MnO_2 - -	43.00
	PbO - -	25.96
	$Al_2O_3 + Fe_2O_3$ -	20.76
	Sb_2O_5 - -	.30
	Cu - - -	Trace
		99.38

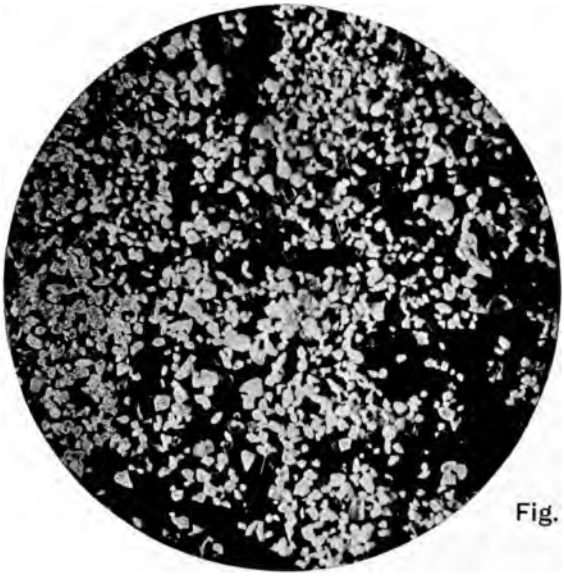


Fig. 1.

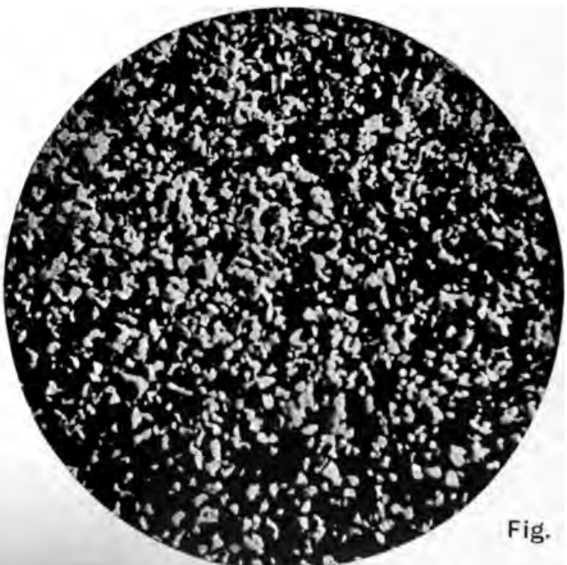


Fig. 2.

I wish to express my sincere thanks to Professor Orme Masson for his constant help and advice throughout this investigation.

I am also indebted to Mr. D. J. Mahony, for undertaking the mineralogical examination of the specimen, and to Mr. H. J. Grayson, not only for the sections he has prepared, but for the micro-photographs illustrating the text.

DESCRIPTION OF PLATE XXIV.

Fig. 1.—Powder consisting of Kaolin and Quartz, before separation.

2.—Quartz-free Kaolin.

(cir. 12 ×).

ART. XV.—*Note on the Stony Creek Basin, Daylesford.*

BY T. S. HART, M.A., F.G.S.

(With Plates XXV., XXVI.).

[Read 13th October, 1904].

The Stony Creek Basin is a relatively low-lying area of about 50 acres situated a short distance to the south of Daylesford. The Stony Creek enters the basin at its south-west corner, flows along its west side, and leaves it at the north-west corner by a narrow gorge. The locality has been mapped in Quarter-sheet 16 S.E. of the Geological Survey of Victoria. The northern and western banks of the basin are capped by basalt, and present a level surface divided by the gorge through which the creek flows out. On both these sides deep leads occur under the basalt, but at higher level than the floor of the basin. On the other two sides the Ordovician bedrock extends to the summit of the bank and reaches levels rather higher than the basaltic plateau. The road from Daylesford to Ballan runs along the top of the east bank. The old alluvials have been worked by tunnels, and also appear on the surface at the north-east corner of the basin.

The central portion of the basin is nearly level, rising towards the east and north sides. Numerous sluicing channels intersect the basin, and expose black clays and shales containing (in the shales) fossil leaves, (eucalyptus, etc.) fruit, (banksia, etc.), and a few coleoptera. The dips of these beds are irregular, both in amount and direction, reaching 45 degs. at one place, where the bedding is most distinct, and possibly vertical on the eastern side of the basin, but the bedding here is obscure. The black clays and shales are covered by newer accumulations on the east and north sides derived from the disintegration on the rocks forming the upper parts of the banks, and hence differing in character. The Stony Creek itself does not expose the black clays and shales, nor are they seen to the west of the creek. The steep banks are much affected by landslips on the east and west sides.

It is evident that though a portion of the basin is occupied by lacustrine deposits, they have been much disturbed since their deposition. The depth to which the black clays extend has not been certainly proved. The shaft of the Grand Mystery Company is the deepest of which I have found any record. The "Daylesford Express" of March 17, 1864, writing of the fourth attempt of this party to bottom the basin, says:—"The drift has been safely gone through in the new shaft, which is about 110 feet from grass, and the bottom of which is covered with waterworn boulders, indicative of the nearness of the gutter. Gold in small quantities has already been found in the shaft." . . . . On April 9 the same paper says:—"This company struck the reef last week at 111 feet, when a large quantity of water flowed in. A prospecting drive was then put in eastward, but after driving 20 feet the black clay was struck in the face of the drive, when it was determined to sink the shaft deeper and open to the north. After supplying new timber to the shaft in the place of that which had been broken by the swelling of the black clay, the further sinking of the shaft was commenced, and it was found that the reef dipped rapidly, one-half of the shaft being in headings, the other in reef at 117 feet. A fair prospect was washed, and it improves as the shaft progresses." Reef in these notices, according to usage of alluvial mining, means bedrock. Beyond this I find no reports of the company's operations except a notice of a 10s. call.

Local miners call this black clay "dyke," and they apply the same term to what is probably a fault rock exposed in the next valley. It is quite possible that they had reached bedrock long before, but had not recognised it till the footwall of the fault was met. This supposition is in accordance with the fact that the shaft was close to the side of the basin, which is here very steep above the level of present surface in the basin, and must continue very steep below. Most likely the limit of the basin on this, the southern, side is a fault. The so-called water-worn boulders may easily have been broken and worn fragments of the bedrock.

It is certain, however, that the floor of the basin lies well below the present creek level, and much below the levels of the [illegible] on is not its original position, and

we need seek no explanation of how a basin of this depth could have been formed and filled. Local opinion frequently refers it to volcanic explosions, of which, however, there are no indications at all. There are no volcanic fragmental rocks, and the lava flows do not originate here.

On the other hand, a number of observations favour the view that there has been here a local subsidence. In the valley of Sailor's Creek, the next valley, at a point north-west of the basin, there is marked on the geological map a broad "dyke" connected by dotted lines with the large Corinella dyke at Eganstown. The gravel in the creek bed conceals much of this area, but wherever I have seen it, it consists of a greyish paste in which are irregularly distributed fragments of the Ordovician bedrock, often of considerable size. It is a belt of fault rock, of considerable width, perhaps accompanied by some intrusive material, though I have seen none here. An undecomposed basaltic dyke occurs a short distance to the south. This belt of broken rock would naturally not be detected on the hill-sides, but conversations with the miners give some support to the view that it extends towards the basin and occurred in the tunnel workings between the place where it is seen and the basin. Similar broken ground seems to occur also in workings in a gully west of Sailor's Creek. At Eganstown the Corinella dyke is shown on the map with a width of 10 or 12 chains. At its western end it is surmounted bv scoriaceous material, forming a low hill; further west in the Deep Creek it appears only as a few thin dykes. East of Eganstown it is exposed with much diminished width in a quarry. A few decomposed dykes are seen in the road cuttings west of Sailor's Creek, and some distance further east beyond the basin similar dykes occur in the cuttings of the Ballarat railway and in the creek bed east of the Jubilee Lake. Continuing, the line leads to Wheeler's Hill, an old point of eruption. If the line were continued to the west it would pass through Mount Moorookyle and McDonald's Hill and others beyond, but the number of these volcanic hills makes coincidence less important. The basin appears to be situated on a line of weakness at the time of the volcanic activity. It lies directly on a line between the hill on the dyke at Eganstown and Wheeler's Hill, and about

midway between them. Black clays similar to those of the basin are found also under the basalt at Sailor's Fall (the same flow which passes the basin) and north of Daylesford railway station, also under volcanic rocks. Here, at the Exchequer Company's shaft, the upper parts were shaly. It is probable that the shaly parts are also uppermost at the basin.

The probable sequence of events is as follows:—The black clays were deposited prior to the volcanic activity, or perhaps during the first modifications of the drainage system by volcanic action. Subsequently, by subsisdence on the course of a well-defined line of weakness, a portion of these black clays have been depressed below the levels of the surrounding country. The creeks of the period flowed west and north of the basin, and may have flooded it. A branch from the lead seems to enter the basin; this would correspond to a diversion of part of the stream into the subsided area. (The lead on the north side is probably a tributary; there is also a small area of basalt east of the Ballan road not shown on the map.) The lava streams from Leonard's Hill have then buried these old valleys, and perhaps part at least of the area of the basin. A part of the waters then flowed down the western side of the basalt forming the present Sailor's Creek. The eastern tributaries formed the present Stony Creek. The course of this creek cutting across the basalt at the outlet from the basin was only able to deepen slowly at this place. While its level was thus maintained it cut out a plain at the site of the basin in these easily-eroded materials. A considerable area of basalt could have been removed at the same time by the creek undercutting it if rested on these clays. When the basaltic barrier at the outlet was cut through, this flood plain was finally deserted, and the talus from the weathering of the steep banks on the north and east sides to some extent covered the plain. It would seem uncertain how much of the disturbance of the east bank is due to the original subsidences and how much to later landslips. It will be noticed that this explanation regards the basin not as a filled-in lake, but as a flood-plain of the creek, formed because of the presence of the easily-eroded lacustrine deposits and the maintenance of the creek level by the basaltic barrier; but

preserving a remnant of once more extensive beds on account of their having been locally depressed.

This adds another to the numerous instances now known showing that local disturbances of deposits about the age of our deep leads occur, and that consequently it is not safe to assume that in working the deep leads they will maintain without variation their original slopes. As early as 1875 Mr. R. A. F. Murray called attention to the difficulty in explaining the direction of fall in some of the Ballarat leads,[1] and noted an instance at Buninyong of a lead dipping both ways.[2] I have since shown that local subsidences can explain the disturbance at this locality, though I suggested a possible explanation also by a succession of volcanic vents.[3]

In 1882 a fault was met with traversing the gutter at the Hepburn Home Paddock Gold Mine. It produced an abrupt change of level in the lead of 23 feet, followed by a greater dip than usual for the next 500 feet of the lead down stream. It is shown in a section prepared by the manager (Mr. J. T. McKenna), and now in the possession of the Ballarat School of Mines. Local subsidences have also recently been given by Professor Gregory as the explanation of an area occupied by tuffs in the workings of the Spring Hill and Central Mine,[4] and for various lakes in the Western District of Victoria.

In conclusion, I desire to thank Mr. H. Herman for a tracing of an unpublished map of the basin made by Mr. S. Hunter.

References.

1.—Geology and Mineral Resources of Ballarat. R. A. F. Murray: Progress Report Geological Survey of Victoria, No. I., pp. 76, 77.

2.—Ibid, Figure 16.

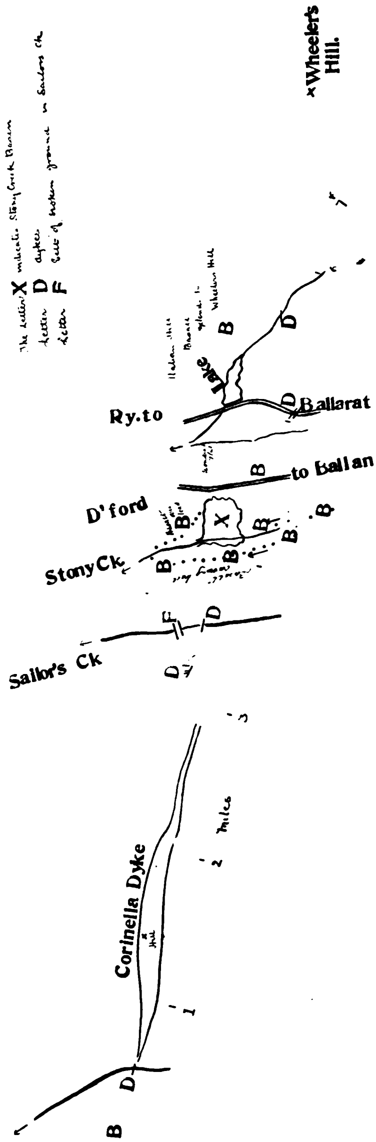
3.—Proc. Roy. Soc. Vic., vol. xii., part 1.

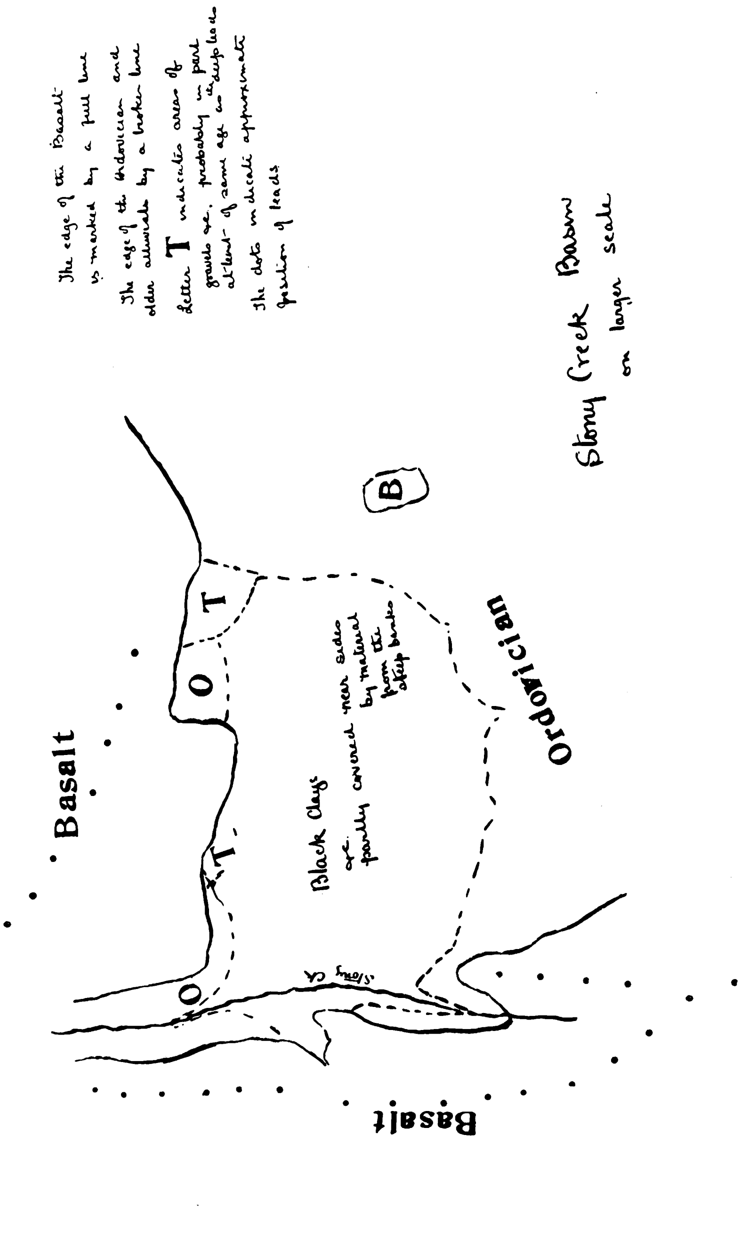
4.—Bulletins of the Geological Survey of Victoria, No 1.

DESCRIPTION OF PLATES.

No. XXV.—Plan showing the position of Stony Creek Basin, and its relation to the Corinella Dyke.

XXVI.—Plan of the Basin on a larger scale.


×Wheeler's Hill.
Lake
Ry. to Ballarat
to Ballan
D' ford
Stony Ck
Sailor's Ck
Corinella Dyke
Miles


The edge of the Basalt is marked by a full line
The edge of the Ordovician and older alluvials by a broken line
Letter T indicates areas of gravels &c. probably in part at least of same age as the deep leads
The dots indicate approximate position of leads
Stony Creek Basin
on larger scale
B
T
O
Basalt
Black Clays &c.
partly covered near sides by material from the steep banks
Ordovician
Stony Ck
Basalt

ART. XVI.—*On Nepharis and other Ants' Nest Beetles taken by Mr. J. C. Goudie at Birchip.*

BY ARTHUR M. LEA, F.E.S.

(Communicated by J. A. Kershaw, F.E.S.).

(With Plate XXVII.).

[Read 13th October, 1904].

Mr. J. C. Goudie, of Birchip, in the Mallee district, of north-west Victoria, has recently been paying considerable attention to ants' nests, with the result that he has obtained many singular forms of beetles in them. All these he has allowed me to see, and of most species has been able to spare several specimens. The collection he has already made is so rich in peculiar forms that I thought a paper containing descriptions of the new species, with notes on the previously described ones, would be of interest. The types of all the new species, and specimens of most of the others, and of two kinds of ants, have been placed in the National Museum, Melbourne.

Some general remarks on ants' nest beetles may not be out of place here, as I have myself paid considerable attention to the nests of ants and termites in many parts of Australia, and have taken many anomalous beetles in them.

On examining a collection of such beetles one cannot help but noticing the large proportion of species having less than the usual number (11) of joints to each of the antennae. The next most noticeable feature is the frequency with which the prothorax is deeply and often very peculiarly sculptured; whilst another peculiarity is the method (usually by ridges or grooves) by which the appendages are protected. In many of the species, moreover, the buccal appendages are often very small, and in some of them quite invisible. In Australia (including Tasmania) but one blind ant's-nest beetle (Tasmanica myrmecophila, Lea) is known, but many are known from Europe and North America.

The beetles more commonly found in ants' nests belong to the families Pselaphidae and Scydmaenidae. In fact, there are but few nests of many kinds of ants that on careful examination will not be found to contain specimens of one family or the other. The genus Articerus, of the former family, contains a larger number of species than any other genus of beetles found with ants in Australia, and specimens of it are sometimes found associated with termites as well; it is readily recognised by its one-jointed antennae. Representatives of its sub-family (the Clavigerides) occur in ants' nests all over the world, and many of them, including several blind genera, are remarkably formed. There are, however, hosts of species to be taken in ants' nests, and probably more than half of the whole family (a large one in Australia) are to be so taken, although many of the species hitherto described have not been so recorded, having been taken during floods, or at sunset on tops of fences, etc., when they have come out to pair. The allied family Scydmaenidae is also rich in species, which occur in ants' nests. The members of both these families are certainly welcomed by the ants, and I have on several occasions seen species of each carrying off Acaridae, which often abound in the nests of ants, and cannot but be injurious to them.

On the other hand, the sculpture of the species of Nepharis and Kershawia is such as to leave no doubt but that they prey upon the ants, and that these are hostile to them; every one of their appendages is admirably protected, the antennae and all parts of the legs fit into appropriate grooves, and even the eyes are protected by tubercles or ridges at their sides, and are unusually small.

The Ptinidae (all of which are apterous) move about very deliberately in the nests, and are apparently untouched by the ants, but they can scarcely be welcome visitors, to judge by the smallness of the palpi and the way their legs are grooved.

There are many species of Staphylinidae to be taken in nests of both ants and termites; of the species known to me most belong to Dabra or to allied genera, but there are several very anomalous forms. Several British species of the family are supposed to be kept as slaves by ants.

One would hardly expect a beetle of the genus Lagria to be found with ants, but I have on several occasions seen a species (formicicola, Lea) of that genus in ants' nests, and of more than one kind of ant; one, indeed, being the ferocious bull-dog ant (Myrmecia sp.), the nests of which, for prudential reasons, one does not care to too critically examine.

Several species of Carabidæ are to be seen in ants' nests, but (except Adelotopus fasciatus, Cast., which is slow moving) they can seldom be taken, owing to the extreme rapidity of their movements, in this respect being second, perhaps, to no other insects in Australia.

Trichopterygidae are to be seen in the nests of some kinds of ants, sometimes hundreds of specimens being in one nest under a stone; they are all fairly fast in their movements, but do not seem to be unfriendly to the ants.

Several species of Arthropterus of the Paussidae are to be taken in ants' nests, and these (judging by other genera of the family which are found with ants) are probably hostile. They all can discharge a stinging vapour from the anus, much as do the Brachinides (Pheropsophus, etc.).

Most of the species of Cryptodus (Scarabaeidae) are to be taken in ants' nests, and all the species have the mouth parts specially protected.

Besides beetles, there are many very peculiar insects to be taken in ants' nests all over Australia. A small cockroach and a small pallid cricket are fairly common. A pale, yellowish, swift-moving silver-fish is very common (possibly there are several congeners). Spring-tails are represented by many species. A number of Hymenoptera are truly parasitic, in their larval stages, on the ants, including species of the remarkable family Mymaridae (of this family I have taken a species, having but two wings, in Tasmania). One Hymenopterous insect, common in ants' nests under stones in Tasmania, is apterous, and with a very peculiar abdomen. Coccidae of the genus Dactylopius and allied genera, abound, being usually seen in the nests attached to roots of grass. Several species of Aphides (so frequently commented on as the "cows" of the ants) are to be taken, and a number of Lepidopterous larvae. Acaridae of many sorts are to be seen, both running about the nests and attached to the bodies of the ants themselves.

The ants, in the nests of which Mr. Goudie found beetles, are Crematogaster laeviceps, Sm., and Iridomyrmex nitidus, Mayr. Mr. W. W. Froggatt (to whom I am indebted for the names) writes me that both are common in New South Wales, about Sydney, and occur also at the Murray River and Bombala. Of the ants Mr. Goudie says:—

"Both the species of ants live, for the most part, in or under dead timber lying on the ground, which has previously been hollowed out by termites; when they get the chance they will kill and eat these latter. In most cases they have holes in the ground under the stick or log, but they do not seem to make much use of them. Their eggs, larvae and winged sexes are often found packed in thousands in a bit of wood a yard long and three or four inches thick, and I have always got the beetles by splitting open the wood; these are generally found in little clusters in the thickest mass of the ants, but nearly always clinging to the solid wood. All the Nephares creep about very slowly and awkwardly."

The beetles occur with the ants as follows:

With *Crematogaster laeviceps*, Sm.

Articerus fortnumi, Hope.
Articerus gibbulus, Sharp (?)
Nepharis goudiei, Lea.

With *Iridomyrmex nitidus*, Mayr.

Dabra myrmecophila, Oll.
Articerus curvicornis, Westw.
Articerus regius, King.
Articerus gibbulus, Sharp (?).
Heterognathus carinatus, King.
Nepharis costata, King.
Nepharis alata, Cast.
Kershawia rugiceps, Lea.
Diphobia familiaris, Oll.
Paussoptinus laticornis, Lea.
Tribolium myrmecophilum, Lea.
Cordus hospes, Germ.

HYMENOPTERA.

Formicidae.

Crematogaster laeviceps, Sm.

(Plate XXVII., Fig. 2.)

This is a small ($3\frac{1}{2}$ mm. in length) reddish-brown ant, with a black, heart-shaped abdomen, and the metathorax with an acute spine on each side.

Iridomyrmex nitidus, Mayr.

(Plate XXVII., Figs. 1, 10 and 11.)

This is a somewhat larger (5 mm. in length) ant, its metathorax without spines and its abdomen oval. Mr. Goudie has sent me winged forms of both the male and female, together with some larvae and pupae.

COLEOPTERA.

Staphylinidae.

Dabra myrmecophila, Oll.

A specimen from Mr. Goudie agrees very well with the description of this species, hitherto known only from Western Australia, where it occurs also in ants' nests.

Mr. Goudie has taken another and a very remarkable species of Staphylinidae, apparently belonging to a new genus near Bledius; but as he has seen but one specimen, I prefer to leave it undescribed at present.

Pselaphidae.

Articerus fortnumi, Hope.

Readily distinguished by the antennae, which "are straight, rather longer than the head, and somewhat narrowed in the middle." It was originally described from Adelaide, but, besides Birchip, occurs also in New South Wales.

Articerus curvicornis, Westw.

Originally recorded from ants' nests in Melbourne. Mr. Goudie has correctly mated the specimens sent to me; the female has much shorter and less curved antennae than the male. The species occurs also in New South Wales, South Australia and Tasmania.

It is the only species of its genus known to me from Tasmania, where it occurs in the nests of Iridomyrmex gracilis, Loun.[1]

Articerus regius, King.

Mr. Goudie has given me a specimen which appears to be a female of this species. It is, at any rate, the only one I have seen having both the prothorax non-foveate and the antennae long. King's specimens were from Liverpool (N.S. Wales) and "ants' nests in wood."

Articerus gibbulus, Sharp. (?)

Mr. Goudie has given me specimens of a species which has the metasternum and middle tibiae as described in the male (the only sex known to Sharp) of this species. The antennae of the Birchip specimens, however, are quite strongly curved at the base (more strongly and regularly than in curvicornis), whilst Sharp says of gibbulus "antennis cylindicis apicem versus incrassatis, apice truncato"; and, again, "The antennae are moderately long, distinctly longer than the head, slender at the base, rather stout at the abruptly truncate extremity." I have not ventured to describe the species as new, however, as the curvature of the antennae, strong as it is, is not noticeable from certain directions, and many of the species of the genus are very widely distributed.

The female of the Birchip species has the metasternum and middle tibiae normal, and the pygidium not impressed.

Mr. Goudie also sent to me for examination several other species of Pselaphidae that were taken by him in ants' nests,

1 I am indebted to Mr. Froggatt for the name of the ant.

but as they were unique specimens, and unknown to me, they were returned, and I unfortunately omitted to note the genera they belonged to.

Scydmaenidae.

Heterognathus carinatus, King.

Described by King from Parramatta, where his specimens occurred "in the nest of small black ants." Mr. Goudie's specimens were taken in the nests of Iridomyrmex nitidus.

The species is distinguished from all its described congeners by the prothorax having a short longitudinal carina at the base, on each side of which is a transverse impression. A closely allied species (perhaps a variety) occurs in Western Australia, in the nests of ants and termites.

Colydiidae.

Nepharis alata, Cast.

(Hiketes thoracicus, King).

(Pl. XXVII., Fig. 5).

Described by both Castlenau and King from specimens taken by Mr. George Masters in an ants' nest at King George's Sound; King did not specify the ant, and I have not seen Castlenau's description. Mr. Goudie appears to have taken a greater number of specimens of it than of either of its congeners.

Nepharis costata, King. (Pl. XXVII., Figs. 4, 8).

Specimens taken by Mr. Goudie agree exactly with two in my collection which were taken by the late Rev. R. L. King at Liverpool, in New South Wales.

Nepharis goudiei, n. sp. (Pl. XXVII., Figs. 3, 9).

Narrow, flattened, reddish-brown, subopaque, glabrous.

Densely covered all over with rather large shallow punctures, smaller on the elytra and coarser on the under surface of the head than elsewhere. Head about once and one-half as long as

wide; with four strong, longitudinal, paralled carinae; apex distinctly notched; sides towards base with several lateral projections. Eyes very small and indistinct, invisible both from above and below. Antennae short, cylindrical, inserted one-third from apex of head, not extending to prothorax, joints very indistinct. Submentum soldered to the head. Prothorax not much longer than head, convex along middle, sides flattened and strongly serrate. Scutellum very short and strongly transverse. Elytra scarcely wider than prothorax, disc convex, and each with four costae, of which only the outer is very distinct, the others (and especially the one near the suture) being but little elevated; costae separating double rows of punctures; sides flattened from base to apex; apex rather deeply notched. Legs short; femora very stout; tibiae dilated towards and obliquely cut off at apex; tarsi (except claw-joint) thin. Length, 2½ mm.

Hab.—Birchip. In nests of Crematogaster laeviceps.

The two median carinae of the head are very distinct from their base to about one-third from their apex, at their base each is feebly bifurcated. The eyes are very small, and it was some time before I could satisfy myself that the species had any at all. The antennae are not clubbed, and, in fact, appear to be perfectly cylindrical throughout, the joints being nowhere distinctly defined, and but for shades of colour (not visible from some directions) marking the junctions of the joints, would appear as if each was composed of but one long cylindrical joint. I have been able to count but eight joints altogether (of which the terminal one is longer and paler than the others), but it is quite possible that there are more.

In the previously described species the piece called by King the submentum is notched behind, and when seen from the sides appears as a kind of flap, which is distinctly separated from the head; but in this species, although slightly notched behind, it forms part of the head itself. This, with the shape of the head, the peculiar antennae and the non-carinate prothorax, might be regarded as causing the species to be generically distinct; but I do not consider it advisable to propose a new genus for its reception, as it is not reasonable to expect uniformity of characters in species leading such abnormal lives as do these insects.

I have not been able to manipulate the legs of any of the specimens of Nepharis so as to be able to draw them in their natural positions, and so in the figures given they have been left out. The antennae of all three species are not very satisfactorily drawn, and, as a matter of fact, it is almost impossible to count the number of their joints in goudiei, and very difficult in costata.

Kershawia, n. g.

Head large, truncated in front. Eyes small, round, lateral, coarsely faceted. Mandibles strong. Maxillary palpi not distinct, the labial with the terminal joint large and in a groove. Antennae eight-jointed.

Prothorax subquadrate, costate.

Scutellum small, transverse.

Elytra subparallel, not much wider than prothorax, costate.

Prosternum with a parallel-sided, feebly elevated ridge from between coxae to base. Intercoxal process of mesosternum widened and notched in front. Metasternum large. Abdomen rather large, composed of five segments, first and fifth larger than the others, which gradually diminish in size.

Legs short and stout. Four front coxae rather narrowly, the hind pair moderately widely separated. Femora grooved and edentate. Tibiae strongly and almost triangularly dilated outwardly, the dilated portion grooved along its outer edge for the reception of tarsi. Tarsi short, linear, apparently four-jointed, the claw joint as long as the others combined. Claws small and simple.

Body winged.

The eight-jointed antennae with small and lateral eyes and the general sculpture denote an approach to Nepharis. The parts of the mouth are not distinctly visible in the specimens before me, and I am not able to see any of the palpi except the terminal joint of the labial pair.

Kershawia rugiceps, n. sp. (Pl. XXVII., Fig. 6).

Of a rusty brown, and (except for the antennae and tarsi) opaque.

Head roughly punctate, with a number of short, costiform, irregularly placed elevations, of which the longest is on each side, above the eye. Antennae short, first joint as long as second-third combined, but partially concealed from above; second-seventh of equal size and strongly transverse; eighth as long as sixth-seventh combined, and increasing in width to apex, which is truncate. Prothorax subquadrate, apex feebly emarginate, base rounded; with four longitudinal costae all united at the base and apex, the outer ones with rounded corners; surface roughly punctate. Elytra each with five costae, the first short and subsutural, the fourth united with third at about one-third from apex, then united with second at one-fourth from apex, then oblique almost to inner apex; surface roughly punctate, the punctures in two more or less regular rows. Under surface and legs densely punctate, the punctures with a granulated appearance. Length, $3\frac{1}{2}$-$4\frac{1}{4}$ mm.

Hab.—Birchip.[1] In nests of Iridomyrmex nitidus.

The head in front is truncate, then rounded and diminishing to about the middle (where the eyes are situated), then dilated and again diminishing to base. The prothoracic costae divide the prothorax into five almost equal longitudinal spaces. On each side of the prosternum there is an oblique ridge, evidently for the protection of the front legs; the middle legs are protected by a ridge on each side of the intercoxal process of mesosternum; whilst the hind legs are protected by a ridge on each side of the middle of the basal segment of abdomen. The antennae (which reach back to just beyond the apex of prothorax) are evidently protected by being laid back below the lateral cephalic costae, with the terminal joint of each resting between the outer costa of the prothorax and its margin.

In two of the specimens before me the sheath of the penis is exposed, but I can detect no external feature characteristic of sex. The under surface appears to be covered with indistinct scales, but these, even under a fairly high compound power, are never clearly defined, and, in fact, what appear to me to be scales may really be mud.

1 This species was known to the late Rev. R. L. King, although he did not describe it. I have a specimen from his collection (now in the Australian Museum) that was apparently taken at King George's Sound, by Mr. George Masters.

Dermestidae.

Mr. Goudie informs me that he has seen numerous larvae apparently belonging to Anthrenus or Dermestes, in the nests; but as yet has taken no images of the family. I have myself, however, recorded a species of it [Trogoderma (Anthrenus) socium, Lea] from ants' nests near Sydney.

Ptinidae.

Diphobia familiaris, Oll.

This is a common insect in the Riverina districts and in some parts of South Australia, where it may often be taken under the bark of various species of Eucalypti, usually in the company of ants. Apparently, however, it is rare at Birchip.

Paussoptinus, n. g.

Head rather small. Eyes small, ovate and lateral. Clypeus large and triangular. Mandibles short and strong. Palpi not visible with head in position. Antennae large and wide, their bases almost touching, second joint almost entirely concealed.

Prothorax longer than wide, towards base with a strong foveate transverse depression, the sides dentate.

Scutellum absent.

Elytra ovate, soldered together.

Mesosternum slightly notched in front. Abdomen wide, with five segments; third much wider but no longer than fifth, slightly shorter than second, and about twice as long as first; fourth very short and distinctly curved.

Coxae large, four anterior free, all largely excavated to receive trochanters; front pair moderately, middle pair more widely, hind pair very widely separated. Trochanters, especially the hind pair, large. Femora grooved to receive tibiae, edentate. Tibiae somewhat compressed, sides grooved to receive tarsi. Tarsi linear and rather thin, all five-jointed, first moderately long second-fourth diminishing in length, and, combined, as long as fifth. Claws small and simple.

Body apterous.

This genus is proposed to receive a small beetle clearly intermediate between the Paussidae and Ptinidae; several other genera have been noted as connecting links between these two families, but there is none so absolutely convincing as this. The head, prothorax, elytra and abdomen strongly resemble those parts of Diplocotes foveicollis, and the legs are much the same; the two insects, in fact, resemble each other so closely that were the antennae removed they would appear to be very closely allied specifically, much more closely, in fact, than foveicollis to its congener howittanus. The antennae (formally described under the species) resemble those of many species of Arthropterus.

The clypeus (or at least what I presume to be the clypeus, as there is a suture on each side separating it from the cheeks) appears as a ridged triangle, of which the apex almost rests between the basal joints of antennae. The mandibles are strong, almost vertical, and close to the front of the prosternum, so that to see the palpi (if these are at all external) it would be necessary to decapitate a specimen. The parts of the legs are so grooved that they can be fitted closely together; but there are no grooves at the sides of the body to still further protect them; the tibiae are apparently without apical spines or mucros.

Paussoptinus laticornis, n. sp. (Pl. XXVII., Fig. 7).

Chestnut-brown; parts of the head, of the antennae and of the legs, darker. Intercoxal processes and middle of metasternum densely clothed with short golden pubescence; sides of prothorax and sides at base of elytra with a few short hairs; elsewhere almost or quite glabrous.

Head transverse; deeper than long, sides at base projecting; coarsely punctate. Antennae extending to second segment of abdomen; first joint thick, curved and coarsely punctate; second small and invisible except from below; third twice as wide as long, moderately stout, convex in front, with punctures as on first; fourth-eleventh each widely transverse and comparatively thin, closely joined together and shining; fourth concave in front and behind; fifth-eleventh, each concave in front and

convex behind; eleventh narrower than tenth, and with its sides rounded and slightly converging towards apex. Prothorax distinctly londitudinally and obliquely strigose, with a large foveate, submedian impression in the middle of a transverse depression; each side bidentate, the front tooth very acute and almost median, the hind very obtuse and at the other side of the depression. Elytra closely applied to prothorax, and at base very little wider than the base of that segment, widest before the middle; strongly convex, sides and apex rounded; seriate punctate, the punctures sub-oblong and distinct but small, the interstices with feeble seriate rows of sparser and smaller punctures; surface with very indistinct but rather numerous transverse wrinkles. Abdomen densely, longitudinally strigose, with irregular transverse series of not very small punctures. Length, 2-3 mm.

Hab.—Birchip. In the nests of Iridomyrmex nitidus and Crematogaster laeviceps.

This is one of the most interesting insects I have seen. From the side, the fourth-eleventh joints of antennae appear thin but moderately inflated in the middle, so as to have a certain resemblance to the seed pods of certain species of Acacia. In some lights their margins seem to be very finely serrated, but this appearance may be deceptive. The transverse depression of the prothorax divides that segment into two parts, of which the basal is not quite half the size of the apical, and is on a lower level. The regular convexity of the elytra is not interrupted by striae. Some specimens, presumably the females, are larger and wider than others; but there are no distinct external features to be noted as sexual.

Tenebrionidae.

Tribolium myrmecophilum, n. sp.[1]

Comparatively broad, chestnut-brown, slightly shining, glabrous.

1 A specimen of this species was sent to Mr. G. C. Champion for his opinion; of it he wrote :—"Your Tribolium is allied to T. confusum which has the antennal joints becoming gradually wider, but your species is larger, etc., and has a smaller apical joint. T. ferrugineum has a well-defined three-jointed club." There are numerous specimens of this species in the King collection that were probably taken in ants' nests near Liverpool.

Head coarsely punctate; in front and on the flanks finely punctate; flanks concealing two basal joints of antennae; with a distinct transverse impression behind eyes. Antennae short, not extending to base of prothorax; seventh-eighth joints rather strongly transverse; ninth-tenth still more transverse, and, with the eleventh, forming a distinct club; eleventh no longer and decidedly narrower than tenth, its sides rounded and apex truncate. Prothorax moderately transverse, sides rounded, apex gently and continuously arcuate and distinctly narrower than base, base feebly bisinuate; densely and coarsely punctate; with several small, irregular impressions. Scutellum small, distinctly punctate. Elytra very slightly wider than prothorax, with a distinct, though narrow, reflexed margin; epipleural fold distinctly punctate; punctate-striate, sutural striae indistinct but punctures clearly defined; interstices with rather large, sparse punctures. Under surface and legs densely punctate; tibiae stout, each minutely bispinose at apex. Length, $4\frac{1}{2}$ mm.

Hab.—Birchip. In nests of Iridomyrmex nitidus.

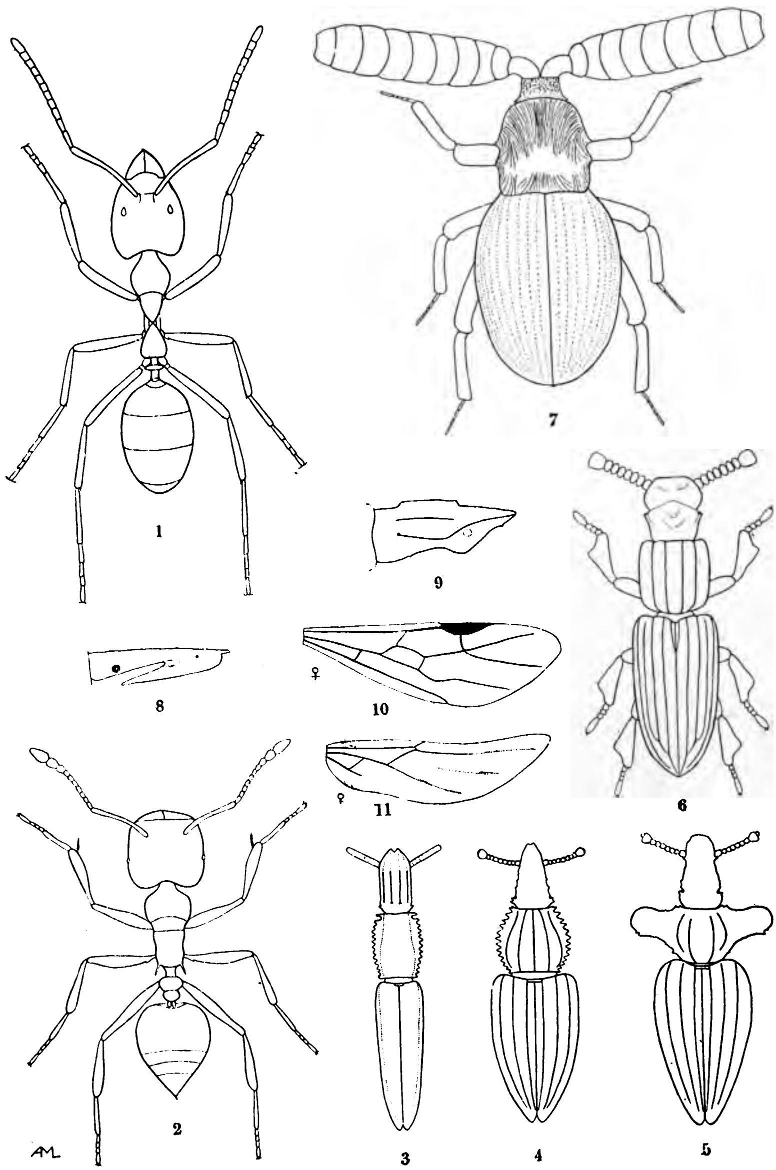
The abdomen is sometimes darker than the upper surface, and the prothorax than the elytra, but the shades of colour are never strongly contrasted. There are usually about six prothoracic impressions, of which four are basal; although sufficiently distinct, they are never sharply defined. I am unable to distinguish the sexes, but some specimens are wider and darker than others.

The species is apparently a common one (Mr. Goudie has sent me 12 specimens) and is readily distinguished from the cosmopolitan confusum and ferrugineum by the small terminal joint of antennae, the much coarser (and on the head not uniform) punctures, wider body, and the apex of prothorax narrower than base. It is about the size and width of Gnathocerus cornutus, but rather darker.

Brenthidae.

Cordus hospes, Germ.

Apparently rare with Mr. Goudie. I have taken it in the nests of termites, as well as in the nests of many species of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ants; and it occurs in Tasmania, as well as in all the States of the mainland.

EXPLANATION OF PLATE XXVII.

Fig. 1.—Iridomyrmex nitidus, Mayr.
2.—Crematogaster laeviceps, Sm.
3.—Nepharis goudiei, Lea.
4.—Nepharis costata, King.
5.—Nepharis alata, Cast.
6.—Kershawia rugiceps, Lea.
7.—Paussoptinus laticornis, Lea.
8.—Side view of head of Nepharis costata.
9.—Side view of head of Nepharis goudiei.
10.—Front wing of Iridomyrmex nitidus.
11.—Hind wing of same.

Art. XVII.—*Lord Howe Island Polyzoa.*

By C. M. MAPLESTONE.

(With Plates XVIII., XIX.).

[Read 14th October, 1904].

I have lately completed the examination of some seventy mounted slides of Polyzoa and numerous fragments of shell and coral with adherent encrusting species on them, which were entrusted to me for that purpose by the Rev. Dr. Porter, of Petersham, New South Wales, who collected them at Lord Howe Island. Lat.: 31°. 30′ S; Long.: 159°. 10′E.

As might be expected, the majority of the species represented in the collection were "Australian," but there were some new species among them.

The following is the list of Australian species found on the Island.

Scrupocellaria cervicornis, Busk.
Tubucellaria cereoides, Ellis and Solander
Beania costata, Busk.
Membranipora membranacea, Linn. sp.
Amphiblestrum spinosum, Quoy and Gaimard sp.
Thalamoporella rosieri, var. falcifera, Hincks.
Cribrilina radiata, Moll. sp.
Schizoporella hyalina, Linn. sp.
,, pachnoides, McG.
,, biturrita, Hincks.
,, cecilii, Audouin sp.
Hippothoa distans, McG.
Smittia trispinosa, Johnston sp.

Two of the specimens of Thalamoporella rosieri var. falcifera, bore ooecia which have not been described. I give an illustration (Fig. 1) showing two of them. They are globular, with a median ridge above the aperture; the operculum is triangular with an acute apex. The other species do not need any comment, except Smittia trispinosa. This is a very variable species: the form from Lord Howe Island is very close to variety "bimucronata," Hincks, which is recorded for Victoria

and to variety "munita," Hincks, which Mr. Waters records from Port Phillip Heads and Green Point, New South Wales, but there is not sufficient difference to warrant its being considered a distinct variety. It is apparently very common there, for there were over a dozen specimens among the slides, and all the fragments of shells, etc., with the exception of three, were encrusted with it.

The new species are:—

Thalamoporella howensis, nov. sp. (Pl. Fig. 2).

Zoaria encrusting. Zooecia elongated, sub-hexangular, with distal margin generally rounded. Surface coarsely granulated or perforated, except a space below the proximal margin of the thyrostome. Margins raised and finely crenate. Thyrostome (opesia?) very large, arched above, irregular below, with a shallow depression at each side and underneath it, in the centre, an internal plate.

A single specimen. This is a very puzzling form; it seems to be intermediate between Steganoporella and Thalamoporella. The general appearance is that of the latter, but the projecting plate under the cryptocyst (?) shows that the structure is very similar to that of Steganoporella; the plate possibly represents the bottom of the "tube" which is present in that genus, and if, as possibly may be the case (as it is not in perfect condition), it had when alive a membranous covering, it would certainly be relegated to that genus.

Schizoporella gibberula, nov. sp. (Pl. Fig. 3).

Zoarium encrusting. Zooecia ovoid, ventricose; surface covered with small tubercles which are connected with each other by an irregular network of narrow raised lines. Thyrostome large, orbicular, with a rounded sinus. An avicularium with a pointed mandible on a large raised elevation on one side. Ooecia globose, subimmersed; surface perforated. This somewhat resembles S. cecilii in appearance, but the shape of the thyrostome is different; the sinus is rounded and shallow, and there is an avicularium on a large umbo on one

side, not always on the same side, and which is not always present; one specimen showed only two or three avicularia, and these had longer mandibles than the type, and the umbos were smaller.

Schizoporella heteromorpha, nov. sp. (Pl. Figs. 4-6).

Adult zooecia indistinct, covered with large tubercles, more or less confluent, some of which project over the thyrostome completely concealing its form, a row of perforations down each side of the zooecium indicating its limits. Some of the tubercles bear pointed avicularia on the summit. The young zooecia are ovoid in shape, ventricose; surface with a few rounded granulations; a row of pores round the lateral margins. Thyrostome transversely elliptical, with a broad sinus in the proximal margin. Ooecia small subglobular, surface sometimes entire but generally composed of large, more or less confluent tubercles.

This is a very variable species. It is only in the young cells that the thyrostome is visible. One is shown at Fig. 4. In older zooecia the tubercles are crowded, and sometimes the rows of marginal pores are very clearly seen, more so than in that one shown in Fig. 5, which is taken from the same fragment as Fig. 4. The oldest form of zooecia is shown in Fig. 6, which also bears ooecia: the tubercles in several places are surmounted with pointed avicularia and the marginal pores are very irregular, only occasionally indicating the margin of the zooecia It would require a great many figures to show all the variations which occur in this species. In the collection sent to me by Dr. Porter there were nineteen mounted specimens, and they were so variable that I at first thought there were several species. Figs. 4 and 5 are taken from the same specimen, from which it will be seen that the variation in a single specimen is very great; there are intermediate forms also in it. In some of the specimens, although the surface was crowded with tubercles, yet the row of marginal pores were almost as regular as in the young zooecia; in others they were not so regular, and, as shown in Fig. 6, they are sometimes very irregular, owing to their being overgrown with tubercles; but they were

always more or less visible, and their presence, together with the tubercular surface, showed that, notwithstanding all these variations, they must be considered as belonging to the same species.

Schismopora cucullata, nov. sp. (Pl. XXIX., Figs. 7, 8).

Adult zooecia globular, subimmersed, irregularly arranged; surface granular. Thyrostome arched above, straight below, with a rounded sinus in the lower margin; large triangular avicularia situated upon large globular bases scattered over the zoarium. The marginal (young) zooecia are decumbent; they have four long thin spines on the distal margin. The thyrostomes of some have a small mucro on the proximal margin, which probably carries a small avicularium; this disappears in the adult form. Ooecia immersed with a hoodlike structure above, the aperture of the same shape as that of the zooecia, but smaller. The zooecia in the older portion of the zoarium are very crowded and irregularly disposed; the hoodlike structure of the ooecia is very peculiar.

Mucronella centrota, nov. sp. (Pl. XXIX., Fig. 9).

Zoarium encrusting. Zooecia elongated, but indistinct; covered with mamilliform tubercles, which in the median line rise up so as to form a ridge. Peristome raised with a long thick spinous projection on each side with two small spines on the distal margin between them; proximal margin very irregularly serrate.

I place this in Mucronella because it is something like M. ellerii in appearance, but the form of the thyrostome is not visible in the specimen, so that its position is somewhat doubtful.

Crisia howensis, nov. sp. (Pl. XXIX., Figs. 10, 11).

Zoaria branching; from three to seven zooecia is an internode. Cells minutely and sparsely punctured, elongated and produced, with a tubular orifice. A long articulated and jointed spine on one side of the zooecial tube. Ooecia ovoid, densely punctured, orifice not visible.

This resembles C. setosa in having a spine growing from the side of the tubular orifice, but the zooecia are very much more elongated and exserted; the spine is not always present.

Crisia cuneata, nov. sp. (Pl. XXIX.. Fig. 12).

Zoaria branching, from twelve to twenty zooecia in an internode. Zooecia very much exserted: the whole surface finely punctured. Ooecia free, obconical, closely punctate; compressed laterally with a flattened distal end on which is an oval aperture. This is a very distinct form.

Specimens of Thalamoporella rosieri var. falcifera and of the new species I have, with Dr. Porter's kind permission, mounted for presentation to the National Museum, Melbourne.

EXPLANATION OF PLATES XXVIII. AND XXIX.

Fig. 1.—Thalamoporella rosieri, var. falcifera.
2.—Thalamoporella howensis.
3.—Schizoporella gibberula.
4.—Schizoporella heteromorpha (young).
5.—Schizoporella heteromorpha.
6.—Schizoporella heteromorpha (ooecia).
7.—Schismopora cucullata (young).
8.—Schismopora cucullata (ooecia).
9.—Mucronella centrota.
10.—Crisia howensis.
11.—Crisia howensis (ooecia).
12.—Crisia cuneata.

Figs. 1, 10, 11 and 12. × 25.
Figs. 2, 3, 4, 5, 6, 7, 8 and 9. × 30.

ERRATA.

Page 386, line 3, *for* xviii., xix., *read* xxviii., xxix.
Page 387, line 10, *after* Pl. *insert* xxviii.
Page 387, line 27, *after* Pl. *insert* xxviii.
Page 388, line 5, *after* Pl. *insert* xxviii.

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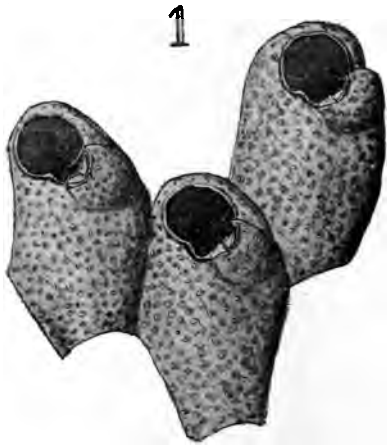

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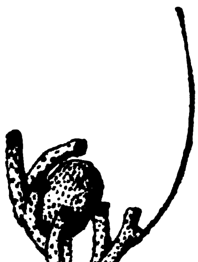

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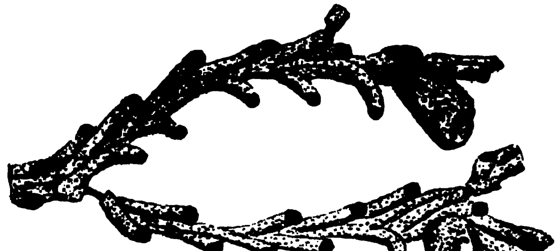

12

Art. XVIII.—*On the Occurrence of Two Species of Cryptoplax in the Tertiary Rocks of Victoria.*

By T. S. HALL, M.A.

(With Plate XXX.).

[Read 10th November, 1904].

The occurrence of two species of Cryptoplax in our Victorian Tertiaries is worthy of notice, as hitherto no fossil representatives of the genus have been found. It is, however, in its recent distribution confined to the south-western Pacific, and the southern shores of Australia, and in its existence as a Tertiary fossil in Southern Australia we have but one more more instance of the essentially Australian character of our Cainozoic fauna.

As regards the age of the two distinct deposits from which the present specimens come, opinions differ. The lower beds of Muddy Creek are by some regarded as eocene and by others as oligocene, while the upper series is generally spoken of as miocene, and was by McCoy considered older pliocene. The question is perhaps not ripe for settlement, though opposing authorities are equally positive in their views. To avoid the constant confusing references to age made in the incidental description of fossils by authors with divergent opinions, Mr. Pritchard and myself have suggested Barwonian, with two subdivisions, Balcombian and Janjukian, for the older series, and Kalimnan for the younger.

The genus Cryptoplax is not uncommon in the Kalimnan, but I have seen only one specimen from the Balcombian.

Cryptoplax pritchardi, n. sp. (Pl. XXX., Figs. 1-6).

All the specimens of the valves that I have found, thirty in number, are much worn and are polished by attrition like so many of the fossils in the Kalimnan of Muddy Creek, and in very few cases is the articulamentum distinctly shown. The valves

approach those of C. gunni very closely in shape, indeed, were shape all that we had to guide us, there would be little justification in separating the fossil from it. In a few cases, however, traces of the sculpture of the tegmentum are preserved and this enables differences of specific value to be pointed out. In C. gunni the coarse grooving radiates from the apex, whereas in the present species faint traces of coarse concentric sculpture are visible. In this point C. pritchardi makes an approach to C. larvaeformis, as figured by Pilsbry.[1] Valve VIII. (see Figs. 3 and 4), allowing for its worn condition, is almost identical in shape with that of C. gunni, the posterior insertion plate being vertical.

Median length of specimen shown in Figs. 1 and 2, 7.5 mm., breadth, 2.5 mm. Median length of original of figs. 3 and 4, 6.6 mm., breadth 2.5 mm., depth 1.6 mm. Length of original of Figs. 5 and 6, 4.0 mm., breadth 4.0 mm.

The resemblance of C. pritchardi to C. gunni is of considerable interest since the latter species, according to the views of Pilsbry,[2] is the most archaic of the five recent species, from the fact that its posterior insertion plate is the least specialised, and approaches that of the normal chitons.

Locality.—"McDonald's," Muddy Creek. Kalimnan (? Miocene). Thirty examples.

Cryptoplax gatliffi, n. sp. (Pl. XXX., Figs. 7-9).

Only a single valve has as yet came under my observation, and this is imperfect anteriorly. The articulamentum is shown on both sides. In shape it differs from any of the valves of C. pritchardi, being less pointed posteriorly. The posterior end is produced downwards into a slight hook-like process, which is shown in side view in Fig. 8. Viewed from below this process is crescentic, as it follows the curve of the valve, and its lower surface is flat. This feature, though absent from the recent species and from C. pritchardi, occurs in some of the other genera of Polyplacophora.

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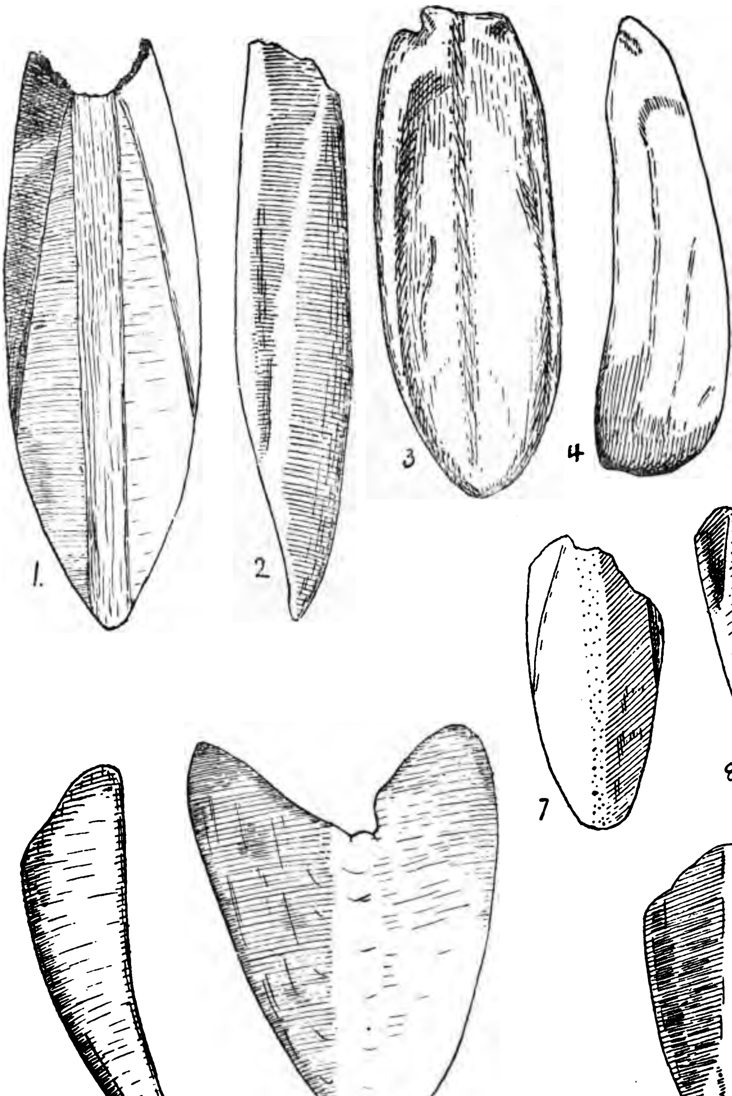
1 Proc. Malac. Soc. 4, 1901, pl. 14, f. 12, 13.
2 *Loc. cit.*, p. 152.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The tegmentum is smooth, being abraded, but traces of a median ridge are traceable, the shell in this region being irregularly and finely pitted. Median length of valve (imperfect) 3.7 mm., breadth 1.9 mm.

Locality.—Clifton Bank, Muddy Creek. Balcombian (? Eocene). A single valve.

The two species are dedicated to Messrs. G. B. Pritchard and J. H. Gatliff, who have done so much in elucidating the recent molluscan fauna of Victoria.

DESCRIPTION OF PLATE.

Cryptoplax pritchardi, n. sp. Figs. 1 and 2, dorsal and lateral views of valve. Figs. 3 and 4, do. of valve VIII. Figs. 5 and 6, do. of (?) valve II.

Cryptoplax gatliffi, n. sp. Figs. 7, 8, 9, dorsal, lateral and internal view of valve.

[All the figures are drawn under the camera, and are magnified to the same scale.]

ART. XIX.—*On an Expeditious Practical Method of Harmonic Analysis.*[1]

BY THOMAS R. LYLE, M.A.,

Professor of Natural Philosophy in the University of Melbourne.

(With Plates XXXI.-XXXIII.).

[Read 8th December, 1904].

1. Fourier has shown that if any function $f(t)$ $(=y$ say) of a variable t be such that

$$f(t)=f(t+\tau)=f(t+2\tau)=\text{etc.},$$

where τ is a constant, that is, if $f(t)$ be periodic in t, of period τ, then $f(t)$ can be expressed as the sum of a constant and a series of terms called harmonics, each of the form

$$a_p \sin p(\omega t-\theta_p),$$

where p has the values 1, 2, 3, 4, etc.,

and $\omega=2\pi/\tau$.

The number p is called the order of the harmonic, a_p its amplitude, and θ_p its phase.

If, in addition, $f(t)$ be such that

$$f(t)=-f(t+\tau/2),$$

then it is easy to see, by substituting $t+\tau/2$ for t, i.e., $\omega t+\pi$ for ωt in

$$y=a_0+\Sigma a_p \sin p(\omega t-\theta_p),$$

that in order for y_t to be $=-y_{t+T/2}$

$$a_0=0,\ a_2=0,\ a_4=0,\ \text{etc.}$$

Hence in this case the constant term vanishes and the harmonics, of which $f(t)$ is the sum, are all of odd order. When such is the case $f(t)$ is called an odd periodic function. This is the type generally met with in alternating electric current investigations.

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1 Appendix to the paper: "Preliminary Account of a Wave Tracer and Analyzer." Phil. Mag., Nov., 1903.

2. If we define the nth component (C_n say) of a periodic function $f(t)$ of period τ as the periodic function which is the sum of those harmonics of $f(t)$ whose orders are n, $3n$, $5n$, $7n$, etc., then

$$2nC_n = f(t) - f\left(t+\frac{\tau}{2n}\right) + f\left(t+2\frac{\tau}{2n}\right) - \quad . \quad . \quad . \quad .$$
$$-f\left(t+\overline{2n-1}\frac{\tau}{2n}\right). \qquad \text{(I.)}$$

For if we represent the expression on the right of the above equation by $\psi(t)$, we find by substituting successively for t, $t+\tau/2n$ and $t+\tau/n$ in it, that

$$\psi(t) = -\psi\left(t+\frac{\tau}{2n}\right) = \psi\left(t+\frac{\tau}{n}\right).$$

Hence $\psi(t)$ is an odd periodic function of period τ/n, that is to say, if

$$f(t) = a_0 + \Sigma a_p \sin p(\omega t - \theta_p),$$

where $p = 1, 2, 3, 4$, etc.,
then $\psi(t)$ is of the form

$$\psi(t) = \Sigma b_q \sin qn(\omega t - \beta_q),$$

where $q = 1, 3, 5, 7, 9$, etc.

In evaluating $\psi(t)$ therefore, only those harmonics whose arguments are $n\omega t$, $3n\omega t$, $5n\omega t$, etc., need be considered. Neglecting all other harmonics in the different f functions that make up $\psi(t)$, we find that the remainders in the $2n$ terms

$$f(t), \quad -f\left(t+\frac{\tau}{2n}\right), \quad f\left(t+2\frac{\tau}{2n}\right), \text{ etc.,}$$

are all equal, and that each remainder is the nth component of $f(t)$, hence

$$\psi(t) = 2nC_n.$$

3. If $f(t)$ itself contain only odd harmonics as in the case of alternate current periodic functions, then

$$f(t) = -f\left(t+\frac{\tau}{2}\right),$$

and equation I., §2, reduces to

$$nC_n = f(t) - f\left(t+\frac{\tau}{2n}\right) + \ . \ . \ . \ + f\left(t+\overline{n-1}\frac{\tau}{2n}\right). \qquad \text{(II.)}$$

The operation on $f(t)$ mathematically represented on the right hand side of equations I. or II., is practically performed on

alternate current waves by the wave tracer and analyzer[1] designed by the author. In the simplest case, when $n=1$, the wave tracer gives the first component of the periodic quantity operated on, which in the case of alternating electric currents is the full wave. By the movement of two pairs of brushes n can be made 3, or 5, or 7; in which cases the analyzer will give the 3rd, 5th, or 7th components of the wave respectively.

Now, in practical investigations with this apparatus on alternating current waves whose harmonic expressions were required, it was found much better to obtain by its means only the full wave trace, and then by an arithmetical process identical with the action of the analyzer and indicated by equation II. above, to obtain the 3rd and higher components of the wave, and thence to deduce its harmonics.

This method of harmonic analysis was drawn attention to in the paper already quoted, and though based on a different formula to that of Wedmore,[2] is practically similar to his. It is more suitable, however, for waves containing only odd harmonics, and as I have had considerable experience in its use during the last two years and have found it both expeditious and accurate, it is possible that a short account may be of value to those interested in alternating current work.

4. In wave graphs it is more convenient to use angular abscissae x where

$$x=\omega t=2\pi t/\tau.$$

Making this substitution in the equation $y=f(t)$ it becomes $y=g(x)$ say, where

$$g(x)=g(x+2\pi),$$

and if $f(t)$ is an odd periodic function as in the case of alternate current waves which we are now considering,

$$g(x)=-g(x+\pi)=g(x+2\pi).$$

Substituting $g(x)$ for $f(t)$ in equation II. it becomes

$$nC_n=g(x)-g(x+\pi/n)+g(x+2\,\pi/n)-\ \ldots$$
$$+g(x+\overline{n-1}\,\pi/n),$$

from which we conclude that, if

1 Lyle: "Preliminary Account of a Wave Tracer and Analyzer." Phil. Mag., Nov. 1903.

2 Wedmore: Journal Inst. Elect. Engineers, vol. xxv., p. 224 (1896).

y_0, y_1, y_2——y_{n-1} be n equi-spaced ordinates that exactly include half the wave, i.e., ordinates corresponding to the abscissae $x,\ x+\pi/n,\ x+2\pi/n,\ \ldots\ x+\overline{n-1}\,\pi/n$ respectively, and called e.s. ordinates in the sequel; and if N_0, N_1, N_2——N_{n-1}, be the ordinates of the nth component C_n whose abscissae are the same as those of y_0, y_1, y_2,——y_{n-1} respectively, then

$$y_0 - y_1 + y_2 - \ \ldots\ + y_{n-1} = nN_0 = -nN_1 = nN_2 = \quad = nN_{n-1}$$

when n is an odd number, and

$$y_0 - y_1 + y_2 - \ \ldots\ - y_{n-1} = 0$$

when n is an even number, as we are now considering odd periodic functions only.

Thus from n e.s. ordinates of the original half wave we obtain only one ordinate per half wave of C_n, so that in order to obtain m e.s. ordinates per half wave of C_n it is necessary to have mn e.s. ordinates of the original half wave.

For instance, to obtain 3 e.s. ordinates of C_n we must measure $3n$ e.s. ordinates of $g(x)$. Let these be

$$y_0,\ y_1,\ y_2\ y_3,——y_{3n-1},$$

and let the corresponding ordinates of C_n be

$$N_0,\ N_1,\ N_2,\ N_3,——N_{3n-1},$$

then

$$y_0 - y_3 + y_6 - \ \ldots\ + y_{3n-3} = nN_0 = -nN_3 = nN_6 = \quad = nN_{3n-3}$$
$$y_1 - y_4 + y_7 - \ \ldots\ + y_{3n-2} = nN_1 = -nN_4 = nN_7 = \quad = nN_{3n-2}$$
$$y_2 - y_5 + y_8 - \ \ldots\ + y_{3n-1} = nN_2 = -nN_5 = nN_8 = \quad = nN_{3n-1}$$

Subtracting now the ordinates of C_n so obtained from the corresponding y ordinates, we obtain a new set of $3n$ e.s. ordinates which are those of the original half wave with its nth component removed.

5. In practice it will generally be sufficient to determine the 1st, 3rd, 5th, 7th and 9th harmonics ($H_1\ H_3\ H_5\ H_7\ H_9$ say). This can be done with considerable accuracy when 15 e.s. ordinates of the original half wave are given.

Thus if these be

$$y_0,\ y_1,\ y_2,\ \ldots\ y_{14}$$

corresponding to the angular abscissae

$$x_0,\ x_1,\ x_2,\ \ldots\ x_{14}$$

where $x_1 - x_0 = x_2 - x_1 = \ \ldots\ = x_{14} - x_{13} = \pi/15$,

and if $z_0,\ z_1,\ z_2,\ z_3,\ z_4$, be 5 e.s. ordinates of the half wave of

C_3, then

$$3z_0=y_0-y_5+y_{10}=-3z_5=3z_{10}$$
$$3z_1=y_1-y_6+y_{11}=-3z_6=3z_{11}$$
$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$
$$3z_4=y_4-y_9+y_{14}=-3z_9=3z_{14},$$

and if u_0, u_1, u_2 be 3 e.s. ordinàtes of the half wave of C_5, then

$$5u_0=y_0-y_3+y_6-y_9+y_{12}=-5u_3=5u_6=-5u_9=5u_{12}$$
$$5u_1=y_1-y_4+y_7-y_{10}+y_{13}=-5u_4=5u_7=-5u_{10}=5u_{13}$$
$$5u_2=y_2-y_5+y_8-y_{11}+y_{14}=-5u_5=5u_8=-5u_{11}=5u_{14}$$

the figure subscribed to each ordinate indicating the abscissa to which it corresponds.

Now the full wave

$$C_1=H_1+H_3+H_5+H_7+H_9+\text{etc.}$$
$$\text{and } C_3= \quad H_3+H_9+H_{15}$$
$$C_5= \quad H_5+H_{15},$$

so that if H_{15} be neglected, and the sums of the corresponding ordinates of C_3 and C_5 be subtracted fram those of C_1, the fifteen remainders are ordinates of

$$H_1+H_7+$$

i.e., of H_1, if we neglect H_7.

If H_{15} cannot be neglected it can at once be removed from C_5 before subtracting from C_1, for as it is (*q.p.*) the 3rd component of C_5, of which we have 3 e.s. ordinates u_0, u_1, u_2, its three corresponding ordinates are i_0, $-i_0$, i_0 where $3i_0=u_0-u_1+u_2$, hence H_5 will de completely given by

$$c_0,\ c_1,\ c_2 \text{ where}$$
$$c_0=u_0-i_0,\ c_1=u_1+i_0,\ c_2=u_2-i_0.$$

H_{15} can now be taken from C_3, thus

$$z_0-i_0,\ z_1+i_0,\ z_2-i_0,\ z_3+i_0,\ z_4-i_0$$

are the 5 e.s. ordinates of H_3+H_9.

In order to determine H_3 and H_9 it will now be necessary to plot the 5 ordinates of H_3+H_9, measure off 6 e.s ordinates from the smooth curve drawn through them, and from these determine their first component, that is 2 e.s. ordinates of H_9. These will completely determine H_9 if H_{27} etc., be neglected, and by subtracting them from the corresponding ordinates of H_3+H_9 6 e.s. ordinates of H_3 are obtained.

If H_7 cannot be neglected it will be necessary (if the original wave trace is not available) to plot the 15 ordinates of

$H_1 + H_7$ obtained above, and from the smooth curve drawn through them to measure off 14 e.s. ordinates. From these, 2 e.s. ordinates of the half wave of H_7, and which determine H_7, can be obtained. By subtracting these from the corresponding ones of $H_1 + H_7$, 14 corrected ordinates of H_1 are obtained.

6. It now remains to determine the amplitudes and phases of the harmonics of C_1 from their ordinates which we have obtained. It is easy to show that

$$\frac{2}{n}\left\{\sin^2\theta + \sin^2\left(\theta + \frac{\pi}{n}\right) + \sin^2\left(\theta + \frac{2\pi}{n}\right) + \quad . \quad . \right.$$
$$\left. + \sin^2\left(\theta + \overline{n-1}\frac{\pi}{n}\right)\right\} = 1,$$

from which we conclude that the square root of twice the mean of the squares of n e.s. ordinates of half a sine wave is equal to its amplitude.

Hence, with the help of a table of squares or of the quarter squares given in most sets of tables the amplitudes of H_1, H_3, etc., can be quickly determined.

[The rule that the amplitude is equal to $\pi/2 \times$ mean of the ordinates is only sufficiently accurate when a large number of ordinates is taken.]

If $a_0, a_1, a_2, \ . \ . \ . \ a_{14}$ be the ordinates we have found for H_1 corresponding to the angular abscissae $x_0, x_1, x_2 \ . \ . \ . \ x_{14}$ respectively, and if h_1, a be the amplitude and phase of H_1 or in other words, if

$$H_1 = h_1 \sin(\omega t - a),$$

then any of the equations

$$\sin(x_0 - a) = a_0/h_1$$
$$\sin(x_1 - a) = a_1/h_1$$
$$\sin(x_2 - a) = a_2/h_1 \text{ etc.,}$$

would determine a, provided the ordinates a_0, a_1, a_2, etc., are exactly those of a sine wave.

In practice, however, small upper harmonics will invariably be left in a_0, a_1, a_2, etc. [it may not have been thought worth while to remove H_7], and though their amplitudes may be negligably small, yet they might cause considerable error in the value of a when determined from only one of the above equations. Hence it

is advisable to obtain four values of a from the first four ordinates on the rising side of the wave and four from the last four ordinates on the falling side, and take the mean of the eight. In this way we can to a great extent eliminate any error that might arise due to a harmonic even as low as the seventh not having been removed.

In a similar way the phases of H_3, H_5 etc., can be determined, but it must be remembered that if, for instance,

$$H_3 = h_3 \sin 3(\omega t - \beta),$$

and if b_0, b_1, . . . b_4 are the ordinates of H_3 corresponding to the abscissae x_0, x_1, . . x_4, then

$$\sin 3(x_0 - \beta) = b_0/h_3 \text{ etc.}$$

similarly, if

$$H_5 = h_5 \sin 5(\omega t - \gamma)$$

with ordinates c_0, c_1, c_2,

$$\text{then } \sin 5(x_0 - \gamma) = c_0/h_5.$$

7. The wave to be analyzed may be given in either of two ways. We may have the complete trace of it obtained by the author's wave tracer by the photographic method, or by any form of oscillograph that gives a trace of the wave form; or we may have the values of a definite number only of ordinates per half wave, such as would be obtained by the author's wave tracer by the galvanometer and scale method.

From the wave trace the complete harmonic expression can theoretically be obtained, but the impossibility of accurately measuring on the photograph, without elaborate apparatus, the different ordinates required leads to great inaccuracy in the result.

From a given number of e.s. ordinates only an approximate analysis can be obtained, more approximate, of course, as the number of ordinates is greater. When, however, each individual ordinate has been obtained with the accuracy of which the galvanometer and scale method is susceptible, the analysis obtained from fifteen such ordinates is much more reliable, as far as the harmonics up to the 9th are concerned, than that determined from any photographic trace.

I will therefore illustrate the method by applying it in full detail to the analysis of the wave whose 15 e.s. ordinates are

Table 1.

Abscissae (ωt)	12°	24°	36°	48°	60°	72°	84°	96°	108°	120°	132°	144°	156°	168°	180°	192°	204°
$H_1+H_7+H_{11}$	35	250	435	597	752	881	955	976	968	933	847	706	542	372	182	−35	−250
$-H_5$	43	4	−39	−43	−4	39	43	4	−39	−43	−4	39	43	4	−39		
$-C_3$	−73	35	135	182	153	73	−35	−135	−182	−153	−73	35	135	182	153		
Given ord^s^ - $f(t)$	65	211	339	458	603	769	947	1107	1189	1129	924	632	364	186	68		
	924	632	364	186	68												
	989	843	703	644	671												
	769	947	1107	1189	1129												
$3C_3$	220	−104	−404	−545	−458												
$3C_{15}$	1	−1	1	−1	1												
$3(H_3+H_9)$	219	−103	−405	−544	−459												
	65	211	339	458	603	769											
	947	1107	1189	1129	924	632											
	364	186	68														
	1376	1504	1596	1587	1527	1401											
	1587	1527	1401														
$5C_5$	−211	−23	195														
$5C_{15}$	2	∓2	2	$-\frac{1}{5}[-211+23+195]$													
$5H_5$	−213	−21	193														

Amp. H_1	Phase $H_1 - \alpha$: Sines	angles	$12° - \alpha$
306			
15 625	·0355	2°. 2′	2°. 2′
47 306	·2533	14°. 40′	2°. 40
89 102	·4407	26°. 9′	2°. 9
141 376	·6048	37°. 13′	1 13
194 040			
228 006			
238 144			
234 256	·7152	45°. 40′	2. 20
217 622	·5491	33°. 18′	2. 42
179 352	·3768	22°. 8′	1. 52
124 609	·1854	10° 41′	1 19
73441			16. 17
34596		mean =	2°. 2°
8281			
1826062			
2			
15) 3652124		$\alpha = 9°.58'$.	
243475			
$h_1 = 987$			

Amp. H_3	Phase H_3: Sines	angles	$3(24° - \beta)$
11 990			
2 652	·1907	11°. 0′	11°. 0′
41 006	·7500	48°. 35	12. 35
73984			
32 670	·8500	58. 12	13. 48
2× - 182302	·4056	23. 55	12. 5
5) 364604			49. 28
72921		mean	12. 22
$3h_3 = 540$		$24° - \beta = 4°\text{-}7'$	
$h_3 = 180$ neg.		$\beta = 19°\text{-}53'$ crossing down	

Amp. H_5	Phase H_5: Sines	angles	$5(36° - y)$
11 342	·8212	55°. 12′	55°. 12′
110			
9312			
20764	·0894	5°. 8′	54°. 52′
2			
3) 41528		mean =	55°
13843		$36° - y = 11°$	
$5h_5 = 235$			
$h_5 = 47$		$y = 25°$ crossing up	

$$f(t) = 987 \sin(\omega t - 9°58') - 180 \sin 3(\omega t - 19°53') + 47 \sin 5(\omega t - 25°).$$

given in row 5 of Table I. Every figure necessary in the calculation will be given.

The first row of figures in Table I. are the abscissae x_0, x_1, etc. to which the given ordinates correspond. Space for three rows of figures is left, and then the 15 given ordinates are written down. These are divided into three sets of five each, and the numbers of the middle set are subtracted in order from the sums of first and last set, giving five numbers which are the corresponding ordidates of $3C_3$. Space for two or more rows is left, and the given ordinates are now written down as in the table, in two rows of six each and one row of three, in order. The columns formed are added and the last three of the sums are subtracted from the first three, giving three ordinates of $5C_5$. The first of these minus the second, plus the third, gives one ordinate of $15C_{15}$, whose other ordinates are got by alternating the sign. Subtracting $5C_{15}$ from $5C_5$ we obtain $5H_5$. Having obtained C_{15} we now subtract $3C_{15}$ from $3C_3$ and obtain $3(H_3+H_9)$.

Above the given ordinates write those of C_3 with signs changed (row 4), and above these write those of H_5 with signs changed (row 3). Add rows 3, 4 and 5 to get row 2, in which are the ordinates of $H_1+H_7+H_{11}$ etc. Neglecting H_7, H_{11}, etc., as is done the analysis in Table I., we may consider the figures in row 2 as the ordinates of H_1, and neglecting H_9 we may consider the figures in row 11 as the ordinates of $3H_3$.

The first 15 numbers under Amp. H_1 are the quarter squares of the ordinates of H_1. Twice the sum of these is divided by 15, the number of ordinates, and the quotient is found to be the quarter square of 987. Hence h_1, the amplitude of H_1, is 987. Similarly for the amplitudes of H_3 and H_5.

Under the heading "phase of H_1," in the first column under sines, are the quotients got by dividing the first four ordinates on the rising side of H_1 and the last four on the falling side of H_1 by h_1; in the second column under angles are the corresponding angles, and in the third column are the eight values of $12°—a$ deduced. The mean of these $2°\ 2'$ when subtracted from $12°$ gives the crossing point or phase of H_1 as $9°\ 58'$. Similarly for the phases of H_3 and H_5. It will be noticed that at the crossing point determined for H_3, H_3 crosses down, which is expressed analytically by writing its amplitude negative.

8. It will be noticed in the determination of the phase of H_1 in Table I., that the eight values of $12°—a$ differ considerably from each other, indicating the presence in what we there take for H_1 of a considerable upper harmonic, probably H_7. In order to determine H_7 fourteen e.s. ordinates of the half wave are required. If the wave trace were given these could be measured off from it, but if, as in the case we are considering, only 15 original ordinates are given, it is necessary to plot the 15 ordinates of H_1+H_7 obtained in Table I., and from the smooth curve drawn through them to measure off 14 e.s. ordinates. This has been done and the values obtained are given in row 4, Table II., as well as the calculation necessary for the determination of H_7 and its elimination from H_1+H_7.

What is called the amplitude of H_1 in Table I. is really $\sqrt{2}$ R.M.S. (H_1+H_7), To get amp. H_1 it is better to remove the effect of H_7 by treating it as a correction, thus avoiding error that might be introduced in the plotting. This is easily done, since

$$M.S(H_1+H_7)=\frac{h_1^2}{2}+\frac{h_7^2}{2}$$

hence h_1 (corrected) $=\sqrt{\text{Amp.}(H_1+H_7)^2-h_7^2}$

$$=\sqrt{h_1^2\ (\text{uncorrected})-h_7^2}.$$

In Table II. the corrected crossing point of H_1 is determined, and it is seen to differ in phase only by 2 minutes from the value obtained in Table I.

The difference between the four values of $3(24°-\beta)$ when determining the crossing point of H_3 in Table I. point to the presence of a ninth harmonic, which exists as a third component in H_3+H_9. H_9 can, if desired, be determined by plotting the 5 ordinates obtained in Table I., measuring off from the curve six e.s. ordinates and proceeding as before. It will be found that

$$H_9=3\sin 9(\omega t-13°).$$

9. In Table III. is given most of the work required for the determination of the first six harmonics of a complete wave that contains harmonics both of odd and even orders. Twenty-four e.s. ordinates of the full wave are taken. This number is specially suitable, as it enables us to determine directly C_1, C_2, C_3, C_4

Table III.

Abscissae (ωt)	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°	195°	210°	225°	240°	255°	270°	285°	300°	315°	330°	345°	360°
Given ord^s $f(t)$	101	280	479	609	634	602	535	399	213	77	33	−4	−88	−153	−159	−202	−377	−606	−720	−659	−495	−313	−156	−29
	88	153	159	202	377	606	720	659	495	313	156	29												
$2(H_1+H_3+H_5+\ )$	189	433	638	811	1011	1208	1255	1058	708	390	189	25												
$2(H_1+H_2+H_3+H_4+)$	202	560	958	1218	1268	1204	1070	798	426	154	66	−8												
$2(H_2+H_4+H_6)$	13	127	320	407	257	−4	−185	−260	−282	−236	−123	−33												
	185	260	282	236	123	33																		
$4(H_2+H_6+\ )$	198	387	602	643	380	29																		
$4(H_2+H_4+H_6)$	26	254	640	814	514	−8																		
$4H_4$	−172	−133	38	→			$H_4 = 45 \sin 4(\omega t - 42°)$																	
$4(H_2+H_6)$	198	387	602	643	380	29																		
	380	29																						
	578	416																						
	602	643																						
$12H_6$	−24	−227	→				$H_6 = -19 \sin 6(\omega t - 14°)$																	
$4H_6$	−8	−76	8	76	−8	−76																		
$4H_2$	206	463	594	567	388	105	→ $H_2 = 151 \sin 2(\omega t - 5°)$																	
$2(H_1+H_3+H_5-\ )$	189	433	638	811	1011	1208	1255	1058	708	390	189	25												
	708	390	189	25																				
	897	823	827	836																				
	1011	1208	1255	1058																				
$6H_3$	−114	−385	−428	−222	→		$H_3 = -74 \sin 3(\omega t - 10°)$																	
$2H_3$	−38	−128	−143	−74	38	128	143	74	−38	−128	−143	−74												
$2(H_1+H_5)$	227	561	781	885	973	1080	1112	984	746	518	332	99												

$H_1 + H_5$ [10 e.s. ord^s from plot of]

ωt	15°	33°	51°	69°	87°	105°	123°	141°	159°	177°
H_1+H_5	113	307	413	467	524	557	472	324	210	79
	524	557	472	324						
	210	79								
	847	943	885	791						
	885	791								
$5H_5$	−38	152	→		$H_5 = 31 \sin 5(\omega t - 18°)$					
H_5	−8	30	8	−30	−8	30	8	−30	−8	30
H_1	121	277	405	497	532	527	464	354	218	49

$$H_1 = 540 \sin(\omega t - 2°)$$

$$f(t) = 540 \sin(\omega t - 2°) + 151 \sin 2(\omega t - 5°) - 74 \sin 3(\omega t - 10°) + 45 \sin 4(\omega t - 42°) + 31 \sin 5(\omega t - 18°) - 19 \sin 6(\omega t - 14°)$$

and C_6. To determine C_5, replotting will have to be resorted to if the full wave trace be not available.

At the top of Table III. are written the 24 given ordinates under their corresponding abscissae. From these ordinates the constant term of $f(t)$ has been removed. This can be done by aid of the formula

$$f(t)+f(t+\tau/n)+f(t+2\,\tau/n)+\ \ .\ \ .\ \ .\ \ +f(t+\overline{n-1}\,\tau/n)$$
$$=n[a_0+a_n\sin n(\omega t-\theta_n)+a_{2n}\sin 2n(\omega t-\theta_{2n})$$
$$+a_{3n}\sin 3n(\omega t-\theta_{3n})+\text{etc.}] \qquad \text{(III.)}$$

which can be easily established by the method used in § 2.

From this formula we see that the mean of n e.s. ordinates embracing one period of a periodic function is equal to its constant term, if its nth, $2n$th, etc., harmonics are neglected.

Returning to Table III., we add the second twelve ordinates with their signs changed to the first twelve, in order, and obtain 12 e.s. ordinates of $2C_1$, i.e., of $2[H_1+H_3+H_5+\quad]$. (See equation I., § 2).

Subtracting these from twice the given ordinates, those of $2[H_2+H_4+H_6+\quad]$ are left, and the remainder of the work proceeds as in Table I.

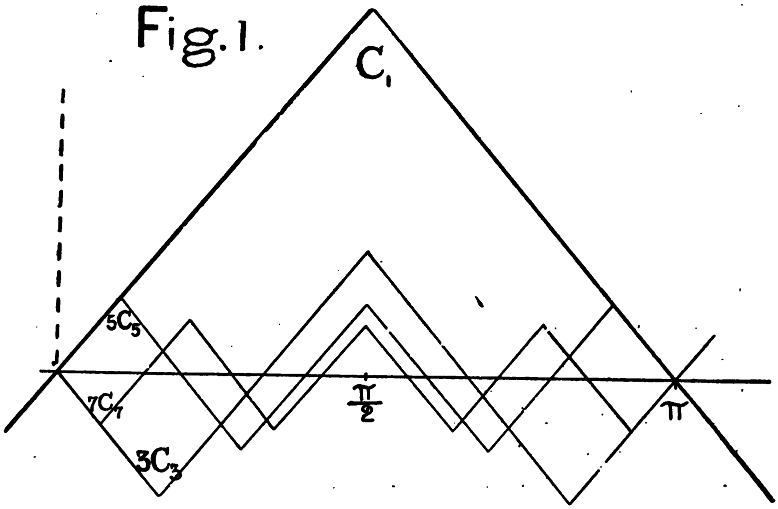
$2[H_2+H_4+H_6+\text{etc.}]$ could be obtained directly from the 24 given ordinates by adding the second 12 to the first 12 of them, in order. (See formula III., § 9).

The amplitudes and phases of the different harmonics were determined as in Table I., but the figures necessary in their calculation are not given.

The following are interesting applications of the above method to more general harmonic analysis.

10. To obtain the harmonic expression for the odd periodic function whose graph for half a period is the sides of an isosceles triangle of altitude h. See Fig. 1.

Taking o and π as the abscissae of the extremities of the base, relative values of any number of e.s. ordinates can be written down, and any component at once obtained. Thus, 30 e.s. ordinates would be 0, 1, 2, 3, . . 14, 15, 14, . . 2, 1, and these correspond to an altitude 15.



It will be found that all the components (i.e. 3rd, 5th, etc., in this case) are the sides of isosceles triangles passing through the origin, and that the altitudes are

$-h/3^2$, $h/5^2$, $-h/7^2$, etc. respectively. (See Fig. 1.).

(The same can be quickly arrived at geometrically).

Hence, if the full wave or C_1 be represented by

$$C_1 = a_1\sin(\omega t - \theta_1) + a_3\sin3(\omega t - \theta_3) + a_5\sin5(\omega t - \theta_5) + \text{etc.},$$

its third component C_3 is

$$= -\frac{1}{3^2}[a_1\sin(3\omega t - \theta_1) + a_3\sin3(3\omega t - \theta_3) + a_5\sin5(3\omega t - \theta_5) + \text{etc.}],$$

and its fifth component C_5 is

$$\frac{1}{5^2}[a_1\sin(5\omega t - \theta_1 + a_3\sin3(5\omega t - \theta_3) + a_5\sin5(5\omega t - \theta_5) + \text{etc.}]$$

and so on, but by definition C_3 and C_5 are also given by

$$C_3 = a_3\sin3(\omega t - \theta_3) + a_9\sin9(\omega t - \theta_9) +$$
$$C_5 = a_5\sin5(\omega t - \theta_5) + a_{15}\sin15(\omega t - \theta_{15}) +$$

hence, identifying the expressions for the same components, we find that

$$a_1 = -3^2a_3 = 5^2a_5 = -7^2a_7 = \text{etc.},$$
$$\theta_1 = 3\theta_3 = 5\theta_5 = 7\theta_7 = \text{etc.},$$

so that

$$C_1 = a_1[\sin(\omega t - \theta_1) - \frac{\sin(3\omega t - \theta_1)}{3^2} + \frac{\sin(5\omega t - \theta_1)}{5^2} - \text{etc.}]$$

But $C_1 = o$ when $\omega t = o$ therefore $\theta_1 = o$;
and $C_1 = h$ when $\omega t = \pi/2$, therefore

$$h = a_1[1 + 1/3^2 + 1/5^2 + 1/7^2 + \text{etc.}] = a_1\pi^2/8$$

hence $a_1 = 8h/\pi^2$ and the Fourier series required is

$$C_1 = \frac{8h}{\pi^2}[\sin\omega t - \frac{\sin 3\omega t}{3^2} + \frac{\sin 5\omega t}{5^2} - \text{etc.}]$$
$$= hN(\omega t) \text{ say.}$$

If the left extremity of the base were at a distance a from the origin instead of coinciding with it, then

$$C_1 = hN(\omega t - a).$$

Let us call the function $hN(\omega t - a)$ an isosceles function, and the series of isosceles triangles which is the graph of $hN(\omega t - a)$ an isosceles wave specified by h its altitude, and a its phase.

11. Any wave containing only odd harmonics whose form is polygonal, with n vertices per half wave, can be resolved into n isosceles waves of the same period, and hence can be analytically represented by a sum of n isosceles functions.

A vertex may or may not occur where the wave crosses the axis of abscissae. In the latter case the base angles of the polygon will be equal.

For the sake of definiteness let us consider the case when the polygon has 4 vertices per half wave, and let it be specified by m_1, m_2, m_3, m_4, m_5, $(m_5 = -m_1)$, the tangents of the angles its sides, taken in the positive direction, make with the axis of x, and by the abscissae x_{12}, x_{23}, x_{34}, x_{45}, of its vertices.

In the first place let us determine the form of the wave got by adding to the above the isosceles wave $I = hN(\omega t - a)$ specified in the above manner by M, $-$M, and X, so that $h = M\pi/2$ and $a + \pi/2 = X$. In general the new wave will have 5 vertices, the abscissa of the one introduced being X, while the abscissae of the others are unchanged, and if X lie say between x_{23} and x_{34}, and the tangents of the slopes of the sides of the new polygon be n_1, n_2, n_3, n_3', n_4, $-n_1$, then, remembering that the equations of the different sides are of the form

$y = mx + \kappa$, we see that

$$n_1 = m_1 + \mathrm{M},\ n_2 = m_2 + \mathrm{M},\ n_3 = m_3 + \mathrm{M},\ n_3' = m_3 - \mathrm{M},$$
$$n_4 = m_4 - \mathrm{M}$$

hence

$$n_1 - n_2 = m_1 - m_2$$
$$n_2 - n_3 = m_2 - m_3$$
$$n_3 - n_3' = 2\mathrm{M}$$
$$n_3' - n_4 = m_3 - m_4$$
$$n_4 - n_5 = m_4 - m_5.$$

Thus, if we call $m_1 - m_2$ the function of the vertex x_{12}, we see that by addition of I to the given wave a new vertex is introduced whose function is equal to that of I ($=2\mathrm{M}$) while the functions of all the other vertices are unchanged. It is easy to see that the function of the vertex of $-I$ is $-2\mathrm{M}$ so that if I be subtracted from the given wave a new vertex is introduced whose function is $-2\mathrm{M}$.

If the abscissa X of the vertex of I correspond with that of one of the vertices of the given polygon x_{23} say, then no new vertex will be introduced by the addition (or subtraction) of I and

$$n_1 - n_2 = m_1 - m_2$$
$$n_2 - n_3 = m_2 - m_3 + 2\mathrm{M}$$
$$n_3 - n_4 = m_3 - m_4$$
$$n_4 - n_5 = m_4 - m_5$$

If in addition $2\mathrm{M} = m_3 - m_2$, then $n_2 - n_3 = 0$ and the vertex or break at x_{23} is removed. Thus, by subtracting from the polygonal wave an isosceles wave whose vertex has the same function and abscissa as a vertex of the given polygon, this vertex of the polygonal wave is removed, while the functions of its remaining vertices are unchanged. To remove each vertex therefore a definite isosceles wave is required, and since, when all vertices are removed the axis of abscissae or $y = 0$ remains, we see that the sum of the several isosceles waves required to extinguish the given wave is equal to the latter.

In the general case, therefore, of a polygonal wave with n vertices, the vertex m_r, m_{r+1}, $x_{r,\,r+1}$, will be removed by subtracting the isosceles wave $I = h\mathrm{N}(\omega t - a)$ where

$$m_r - m_{r+1} = 2\mathrm{M} = 4h/\pi$$
$$x_{r,\,r+1} = \mathrm{X} = a + \pi/2,$$

and the complete wave will be fully represented by the sum of the n isosceles functions given by

$$\frac{\pi}{4}\sum_{r=1}^{r=n+1}\left\{(m_r - m_{r+1})\mathrm{N}(\omega t - x_{r,\,r+1} + \pi/2),\right\}$$

remembering that $m_{n+1} = -m_1$.

The following are examples of the preceding method.

12(a). Wave form a trapezium with equal base angles. This is the sum of two equal isosceles waves.

Take the left extremity of the base of the trapezium as the the origin of abscissae and let it be specified by

$$m_1 = m,\ \ m_2 = o,\ \ m_3 = -m,\ \ a_{12} = \mu,\ \ a_{23} = \pi - \mu.$$

so that its altitude $t = \mu m$.

By § 11 the expression for the wave is

$$\frac{\pi m}{4}[\mathrm{N}(\omega t - \mu + \pi/2) + \mathrm{N}(\omega t + \mu - \pi/2)]$$

$$= \frac{2m}{\pi}\Big[\sin(\omega t - \mu + \pi/2) - \frac{\sin 3(\omega t - \mu + \pi/2)}{3^2} + \text{etc.}$$

$$+ \sin(\omega t + \mu - \pi/2) - \frac{\sin 3(\omega t + \mu - \pi/2)}{3^2} + \text{etc.}\Big]$$

$$= \frac{4t}{\mu\pi}\Big[\sin\mu\sin\omega t + \frac{\sin 3\mu\sin 3\omega t}{3^2}$$

$$+ \frac{\sin 5\mu\sin 5\omega t}{5^2} + \text{etc.}\Big],$$

which is Fourier's expansion for a wave of this form.

12(b). Wave form a triangle. This is the difference of two isosceles waves when the vertex of one lies on a side of the other.

Take the left extremity of the base of the triangle as the origin of abscissae and let it be specified by

$$m_1 = m,\ \ m_2 = -n,\ \ m_3 = -m,\ \ a_{12} = \mu,\ \ a_{23} = \pi$$

so that its altitude $h = \mu m = (\pi - \mu)n$, and m, n, are the tangents of its base angles.

By § 11 its expansion in isosceles functions is

$$\frac{\pi}{4}[(m+n)\mathrm{N}(\omega t - \mu + \pi/2) + (m-n)\mathrm{N}(\omega t - \pi/2)]$$

$$= \frac{\pi m}{4}[\mathrm{N}(\omega t - \mu + \pi/2) + \mathrm{N}(\omega t - \pi/2)] + \frac{\pi n}{4}[\mathrm{N}(\omega t - \mu + \pi/2)$$

$$- \mathrm{N}(\omega t - \pi/2)]$$

which is

$$=\frac{4m}{\pi}\left[\sin\frac{\mu}{2}\sin(\omega t-\mu/2)+\frac{\sin\frac{3\mu}{2}\sin3(\omega t-\mu/2)}{3^2}+\text{etc.}\right]$$

$$+\frac{4n}{\pi}\left[\cos\frac{\mu}{2}\cos(\omega t-\mu/2)+\frac{\cos\frac{3\mu}{2}\cos3(\omega t-\mu/2)}{3^2}+\text{etc.}\right]$$

where $m\mu=n(\pi-\mu)=h$.

When $\mu=120°$ the above expression for the triangle reduces to

$$3\sqrt{7}\frac{h}{\pi^2}\left\{\sin(\omega t-\beta)-\frac{\sin(5\omega t-\beta)}{5^2}+\frac{\sin(7\omega t-\beta)}{7^2}-\text{etc.}\right\}$$

$$+\frac{4h}{3\pi^2}\left\{\cos3\omega t+\frac{\cos9\omega t}{3^2}+\frac{\cos15\omega t}{5^2}+\text{etc.}\right\}$$

where $\tan\beta=\frac{1}{3\sqrt{3}}$.

12(c). Wave form a polygon with n vertices per half wave and such that the functions of its vertices are all equal and also the projections of its sides on the axis of x.

Let $q=m_1-m_2=m_2-m_3=m_3-m_4=\text{etc.}=m_n+m_1$ and let the abscissae of its vertices be a, $a+\pi/n$, $a+2\pi/n$, . . $a+(n-1)\pi/n$ then by § 11 the expression for the wave is

$$\frac{\pi q}{4}\Sigma\,.\,\mathrm{N}(\omega t+\pi/2-[a+r\,\pi/n])$$

where r has all values from o to $n-1$.

Substituting for the N functions their equivalent harmonic series, summing the terms that have the same arguments and remembering that $nq=2m_1$, the expression for the polygonal wave under consideration becomes

$$\frac{4m_1}{n\pi}\left\{\frac{1}{\sin\frac{\pi}{2n}}\sin(\omega t-a+\pi/2n)+\frac{1}{3^2\sin\frac{3\pi}{2n}}\sin3(\omega t-a+\pi/2n)\right.$$

$$\left.+\frac{1}{5^2\sin\frac{5\pi}{2n}}\sin5(\omega t-a+\pi/2n)+\text{etc.}\right\}$$

12(d). If in example (c) n become infinite the polygon becomes a smooth curve satisfying the following conditions

$$\frac{d^2y}{dx^2}=\text{const.}$$

$\frac{dy}{dx}=m_1$ when $x=o$ and $=-m_1$ when $x=\pi$,

$y=o$ when $x=o$ and when $x=\pi$.

This curve is the parabola

$$y=m_1x-\frac{m_1}{\pi}x^2,$$

whose axis is $x=\pi/2$ and vertex $x=\pi/2$, $y=m_1\pi/4$, and the harmonic expression for the wave of which it is the type is obtained by making $n=\infty$ and $a=o$ in the expression in (c) and is

$$\frac{8m_1}{\pi^2}\left\{\sin\omega t+\frac{\sin 3\omega t}{3^3}+\frac{\sin 5\omega t}{5^3}+\text{etc.}\right\}$$

13. To find the harmonic expression for the complete periodic function whose graph for one period is made up of the sides of two equal and similar triangles ABC and A′BC′ so placed that A′ and C′ lie in AB and CB produced respectively. Take A as origin, then the abscissae of B and A′ will be π and 2π respectively and let the abscissa of $\text{C}=\mu$ hence that of $\text{C}'=2\pi-\mu$.

By geometrical construction the different components of this wave can be easily obtained if we remember formula 1 § 1.

Thus to get the 2nd component we cut the wave in four portions by ordinates at $\pi/2$, π, $3\pi/2$, 2π, invert the second and fourth portions, superpose them and the third portion on the first, add the corresponding ordinates, divide each sum by four and the plot of the results will be a half wave, which gives the 2nd component.

It will be found for the wave under consideration that all the components are, in general, trapeziums of the type treated in § 12 (a); and if the trapezium which is the rth component be specified as in § 12 (a) by m_r and μ_r measured on the original scale of abscissae, it will be found that

$$m_r=\pm\frac{\tan A+\tan B}{2r}$$

(i.e. that $2r$ times the function of its vertex is equal to $\pm$ the function of the vertex of the triangle)

and that

$$\sin r\mu_r=\pm\sin r\mu$$

the same signs being taken together.

It is to be noted that as the base of the rth component is π/r the altitudes of its isosceles elements are each

$$=\frac{\pi}{2r}\mathrm{M}=\frac{\pi}{4r}m_r$$

its expression in isosceles functions is

$$\frac{\pi m_r}{4r}\left\{\mathrm{N}r(\omega t-\mu_r+\frac{\pi}{2r})+\mathrm{N}r(\omega t+\mu_r-\frac{\pi}{2r})\right\}$$

and its harmonic expression is

$$\frac{4m_r}{r\pi}\left\{\sin r\mu_r\sin r\omega t+\frac{\sin 3r\mu_r\sin 3r\omega t}{3^2}+\text{etc.}\right\}$$

Hence the rth component

$$\mathrm{C}_r=\frac{2(\tan\mathrm{A}+\tan\mathrm{B})}{\pi r^2}\left\{\sin r\mu\sin r\omega t+\frac{\sin 3r\mu\sin 3r\omega t}{3^2}\right.$$
$$\left.+\frac{\sin 5r\mu\sin 5r\omega t}{5^2}+\text{ etc. }\right\}.$$

If h be the altitude of either of the given triangles, then

$$h=\mu\tan\mathrm{A}=(\pi-\mu)\tan\mathrm{B}$$

and the development for the complete wave is

$$f(t)=\frac{2h}{\mu(\pi-\mu)}\left\{\sin\mu\sin\omega t+\frac{\sin 2\mu\sin 2\omega t}{2^2}\right.$$
$$\left.+\frac{\sin 3\mu\sin 3\omega t}{3^2}+\text{etc.}\right\}.$$

ANNUAL REPORT OF THE COUNCIL

FOR THE YEAR 1903.

The Council of the Royal Society herewith presents to the Members of the Society the Annual Report and Statement of Receipts and Expenditure for the year 1903.

Meetings were held as follows :—

March 10.—Annual Meeting and Election of Officers. Ordinary Meeting. Paper read: "The Geology of the Valley of the Lower Mitchell River," by J. Dennant, F.G.S., F.C.S., and D. Clark, B.C.E.

April 16.—Papers read: 1. "On the Occurrence of Striated Boulders in the Permo-Carboniferous Rocks near the Mouth of the Shoalhaven River, New South Wales," by E. O. Thiele. 2. "On Certain Conglomerates near Sydenham," by T. S. Hart, M.A., F.G.S. Exhibits: 1. Spirulirostra curta, Tate, from Spring Creek, by Mr. T. S. Hall. 2. Mr. E. J. White discussed Mr. H. C. Russell's theory of the nine year's periodicity of droughts.

May 14.—Papers read: 1. "On some Fossil Tertiary Pleurotomarias," by G. B. Pritchard. 2. "New or Little-known Victorian Fossils in the National Museum; Part 2, Some Silurian Species," by F. Chapman, A.L.S. Exhibit: Fossils, in illustration of his paper, by Mr. Chapman, on behalf of the Trustees of the National Museum.

June 11.—Papers read: 1. "Volcanic Necks at Anderson's Inlet, South Gippsland," by A. E. Kitson, F.G.S. 2. "Ice Deposits at Taminick, Glenrowan and Greta," by A. E. Kitson, F.G.S. 3. "Catalogue of the Marine Shells of Victoria, Part 7," by G. B. Pritchard and J. H. Gatliff. 4. "New Species of Victorian Marine Mollusca," by G. B. Pritchard and J. H. Gatliff. Exhibits: 1. Photographs and specimens, in illustration of his paper, by Mr. Kitson. Three species of Victorian Chiones, by Messrs. Pritchard and Gatliff.

July 12.—Papers read: 1. "Further Descriptions of Victorian Tertiary Polyzoa, Part 9," by C. M. Maplestone. 2. "Some

Features in the Geography of North-Western Tasmania," by Professor J. W. Gregory. 3. "On the Occurrence of Older Tertiary Fossils at Hexham, Victoria," by T. S. Hall. Exhibits: Photographs, in illustration of his paper, by Professor Gregory.

August 13.—Paper read: "Some Foraminifera and Ostracoda from the Jurassic (Lower Oolitic) of Western Australia," by F. Chapman, A.L.S. Exhibits: 1. Specimens, in illustration of his paper, and Spore Coals, by Mr. Chapman. 2. Ambergris, by Mr. E. J. Dunn, F.G.S. 3. Species of Unio, by Mr. J. Dennant, F.G.S. 4. Newt, by Mr. T. S. Hall. Professor Kernot described the Site of the recent accident in the Paris Underground Railway.

September 10.—1. Mr. John Byatt gave an Address on Monumental Brasses, illustrated by a series of rubbings. 2. Mr. J. Aebi gave a demonstration of Modern Methods in Photo-Engraving.

October 8.—Papers read: 1. "Notes on Victorian Selenariidae and Descriptions of some New Species, Recent and Fossil," by C. M. Maplestone. 2. "Revision of Australian Lepidoptera, Fam. Geometridae," by Dr. A. Jefferis Turner, M.D., F.R.S. Exhibits: 1. A series of Lantern Slides and Rock Sections, illustrating the structure of a coral island, by F. Chapman. 2. Hyalonema sieboldi, by the Biological Department, University. 3. Skeletons of Cat, Squirrel and Mole, mounted to show relations of bones to outline of body, by Mr. J. A. Kershaw, for the Trustees of the National Museum.

November 12.—Papers read: 1. "The Geology of the Barwon Valley, about Inverleigh," by T. S. Hall and G. B. Pritchard. 2. "The Auriferous Sandstones of Chiltern," by E. J. Dunn, F.G.S. Exhibits: Specimens and Photographs in illustration of papers, by Mr G. B. Pritchard and by Mr. E. J. Dunn.

December 10.—Papers read: 1. "Field Practice with the Aneroid Barometer," by Professor W. C. Kernot, M.A., M.C.E. 2. "An Unnoticed Feature in the Faulting at Ballarat East," by T. S. Hart, M.A., F.G.S. 3. "On a Collection of Palaeozoic and Mesozoic Fossils from Queensland and Western Australia in the National Museum," by F. Chapman, A.L.S. 4. "New or Little-known Fossils in the National Museum; Part III.—Some Palaeozoic Pteropoda," by F. Chapman, A.L.S.

The Society held a very successful Conversazione at the Athenaeum Hall on 1st September.

During the year five members, one country member and five associates were elected, and three members and two country members resigned.

Dr. A. R. C. Selwyn, one of the founders of the Society, and an honorary member, died in Canada, after a long life passed in the promotion of scientific knowledge.

The Council is glad to record that a member of the Society, Mr. A. W. Howitt, F.G.S., is the recipient of the first award of the Mueller Medal, by the Australasian Association for the Advancement of Science.

The "Proceedings" of the Society, New Series, Vol. XV., Part II. and Vol. XVI., Part I., were published during the year.

The Council regrets to have to announce that the Government grant has been further reduced, and now amouuts to only £50. The Council would urge members and associates to endeavour to increase the membership roll, and thus supply the means of publishing the papers that are continually being brought before them. The Society's Library of about 6000 scientific periodicals has been acquired solely by exchange, and contains volumes not found in any other library in the State. There are many publications the Council would like to subscribe to, but cannot do so for lack of funds. The questions of binding and shelving are pressing ones, but in this and in other ways, the state of the Society's finances prevents the Council from maintaining the property of the Society in a proper condition.

During the year the Library was increased by the addition of 1283 volumes and parts. New shelving to the extent of about 100 feet has been added, but is nearly all occupied, and as there is now no further room for shelving in either the library itself, or in the council room, the cost of any additional shelving will be considerable.

The Council would again urge upon members the imperative necessity of increasing the income of the Society in what, at present, appears to be the only possible way, namely, by additions to our roll of members and associates.

The Honorary Treasurer in Account with the Royal Society of Victoria.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance from 1901	£59	16	0	By Printing and Stationery	£141	13	6
Government Grant	50	0	0	Postages	19	3	8
Subscriptions—				Freight and Sundries	5	8	7
Members	50	8	0	Salary of Assistant-Secretary	22	18	4
Country Members	3	3	0	Custodian	6	0	0
Associates	28	7	0	Rates	5	13	4
Arrears	14	14	0	Insurance	5	1	3
Rent of Rooms	6	15	0	Repairs	3	14	6
Interest	9	0	0	Sewerage Connections	5	8	6
Sale of Materials	0	10	2	Books and Periodicals	2	8	0
Transfer from Publishing Fund ...	100	0	0	Furniture and Fittings	8	7	0
				Collector's Commission	9	0	0
				Gas and Fuel	6	7	9
				Refreshments	5	7	5
				Conversazione	20	3	0
					£266	14	10
				Balance	55	18	4
	£322	13	2		£322	13	2

PUBLISHING AND RESEARCH FUND.

Dr.		Cr.	
To Balance from 1902	£300 0 0	By Transfer to General Account	£100 0 0
		Balance (on Fixed Deposit in Bank of Australasia)	£200 0 0
	£300 0 0		£300 0 0

Compared with the Vouchers, Bank Pass-Book, and found correct,

H. MOORS,
JAMES E. GILBERT, } *Auditors.*

P. DE JERSEY GRUT,
Hon. Treasurer.

3rd March, 1904.

Royal Society of Victoria.

1904.

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1904.

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WITH THEIR YEAR OF JOINING.

PATRON.

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Neumayer, Prof. George, Ph.D., Hamburg, Germany ... 1857

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Hartnell, W. A., "Irrewarra," Burke Road, Camberwell 1900
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Hogg, E. G., M.A. 1890
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Lyle, Prof. T. R., M.A., University, Melbourne ... 1889
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Heden, E. C. B., B.A., B.Sc., B.E., School of Mines, Castlemaine 1904
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, James, Dana-street, Ballarat, Victoria 1882
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ng, Isaac, C. E., Ballarat, Victoria 1892

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y, F. M., F.L.S., Government Botanist, Brisbane, Queensland 1880

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idge, Robert, Junr., Australian Museum, Sydney, N.S.W. 1877

s, Professor G. B., LL.D., F.R.S., Royal College of Science, S. Kensington, England 1898

s, A. H. S., M.A., B.Sc., Sydney Grammar School, Sydney, N.S.W. 1895

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rson, J., 225 Beaconsfield Parade, Middle Park ... 1903

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well, Rev. A. W., M.A., St. John's Parsonage, Camberwell, Victoria 1887

s, A. T., 391 Bourke-street west, Melbourne ... 1883

Ferguson, W. H., Maryland Villa, Camberwell Road Camberwell 1894

Finney, W. H., 40 Merton-street, Albert Park 1881
Fison, Rev. Lorimer, M.A., D.D., Essendon, Victoria ... 1889
Fulton, S. W., 369 Collins-street, Melbourne 1900

Gabriel, J., Victoria-street, Abbotsford, Victoria ... 1887
Gatliff, J. H., Commercial Bank of Australasia, Lygon-street, Carlton 1898
Goodwin, A. J., 43 St. George's Road, N. Fitzroy ... 1900
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Grayson, H. J., University, Melbourne 1902

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Herman, Hyman, B.C.E. 1897
Holmes, W. A., Telegraph Engineer's Office, Railway Department, Melbourne 1879

Ingamells, F. N., Observatory, Melbourne 1889

Jobbins, G. G., Electric Lighting Coy., 31 Queen-street, City 1902
Jutson, J. T., "Oakworth," Smith Street, Northcote ... 1902

Kenyon, A. S., Heidelberg... 1901
Kernot, Frederick A., 57 Russell-street, Melbourne ... 1881
Kitson, A. E., F.G.S., Mining Department, Melbourne 1894

Lambert, Thomas, Bank of New South Wales, Collins-street, Melbourne 1890
Le Souef, D., C.M.Z.S., Royal Park, Melbourne 1894
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Menz, R. 1902

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O'Neill, W. J., Lands Department, Melbourne 1903

Phillips, A. E., Box 396, G.P.O., Melbourne 1883
Pritchard, G. B., Mantell-street, Moonee Ponds, Victoria 1892

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Schafer, R., "Invercloy," Napier-street, Essendon ... 1883
Shaw, Alfred C., Bond-street, Abbotsford, Victoria ... 1896
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Smith, G. P., "Earlscourt," Glenferrie-road, Hawthorn ... 1901
Stephen, Rev. R., M.A., Trinity College, Parkville ... 1901
Stewart, C., M.C.E., Shire Hall, Preston 1883
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Thiele, E. O., School of Mines, Sale 1898
Tisdall, H. T., 7 Washington-street, Toorak 1883
Traill, J. C., B.A., B.C.E., "Ormea," Mercer-road, Malvern 1903

Wedeles, James, 231 Flinders Lane, Melbourne 1896
Weindorfer, G., Austro-Hungarian Consulate, Melbourne 1903
Woodward, J. H., Queen's Buildings, Rathdowne-street, Carlton 1903

INDEX.

(The names of new genera and species are printed in Italics).

END OF VOLUME XVII.

[PART II. ISSUED FEBRUARY, 1905.]

PROCEEDINGS

OF THE

Royal Society of Victoria.

VOL. XVIII. (New Series).

PART I.

Edited under the Authority of the Council.

ISSUED AUGUST, 1905.

(Containing Papers read before the Society during the months of March, April, June and July, 1905).

MELBOURNE:
FORD & SON, PRINTERS, DRUMMOND STREET, CARLTON.

AGENTS TO THE SOCIETY:
WILLIAMS & NORGATE, 14 HENRIETTA STREET, COVENT GARDEN, LONDON.

To whom all communications for transmission to the Royal Society of Victoria, from all parts of Europe, should be sent.

1905.

CONTENTS OF VOLUME XVIII.—PT. I.

[PROC. ROY. SOC. VICTORIA, 18 (N.S.), PT. I., 1905].

ART. I.—*On a Palaeozoic Serpentine Conglomerate, North Gippsland.*

BY E. O. THIELE.

(With Plate I.).

[Read 9th March, 1905].

The conglomerate under consideration belongs to a serpentine belt and associated series of basic igneous rocks of undetermined area. It is situated in the parish of Dolodrook, county of Wonnangatta, about 7 or 8 miles in a straight line west from Mt. Wellington. The country is rough and precipitous, so that the very short time available for examining the occurrence did not permit of any attempt being made to trace the boundaries of the serpentine and igneous rocks. This series of rocks, however, apparently forms a belt of no great width, and stretches south-easterly from a point about a mile-and-a-half south-east of the junction of the Wellington River with a stream which it is proposed to name the Dolodrook River. This tributary enters on the left bank of the main stream, but is unfortunately locally known as the Right Branch of the Wellington. Mr. R. A. F. Murray, in his report on the "Geology of South-East Gippsland,"[1] mentions the fact that he was unable to investigate the area immediately to the west of Mt. Wellington, but that it was nearly certain to afford geological features of interest, as he had heard of the occurrence of serpentine from that district, and that the sample of chrome iron ore mentioned in Progress Report, No. III., p. 172, came from the same place. The rocks of the greater part of the Mt. Wellington district consist of coarse red to chocolate coloured conglomerates, sandstones, finer shales and a varied series of igneous rocks forming an extensive Upper Palaeozoic belt, extending north-westerly across the Main Divide to Mansfield.

1 Progress Report, No. V., Geol. Surv. Vic., p. 57.

This series has been described as Devonian, but the northern portion is now generally accepted as Carboniferous, chiefly on account of the revision of the fossil fish from the Mansfield district by A. Smith Woodward, LL.D., F.R.S.[1] As, however, our knowledge of the relation of the southern part of this region to the Mansfield series is scanty, it is thought preferable at present to refer to the rocks of the Mt. Wellington series as simply Upper Palaeozoic.

At the junction of the Wellington River with the Dolodrook River, the writer obtained a series of well preserved graptolites from highly inclined black slates. These fossils have been handed over to Mr. T. S. Hall, M.A., who intends to work them shortly. Mr. Hall says that these graptolites represent an undoubted Upper Ordovician age, and, as the associated rocks were traced for some miles along the Wellington River and also observed in numerous sections along the Dolodrook River, an extensive inlier of Ordovician rocks is thus shown to exist in the Upper Palaeozoic area. The older rocks are much folded and in places show faulting accompanied by considerable crushing and crumpling. The Upper Palaeozoic rocks show little disturbance and rest unconformably on the Ordovician series with a general prevailing dip westerly, in this locality, at a low angle.

The observations in the serpentine area were confined principally to an interesting conglomerate noted at the north-west end of the serpentine belt.

The occurrence was reached by following up the Dolodrook River from its junction with the Wellington for less than half-a-mile, and then branching off to the left up a small steep tributary gully, locally known as Black Soil Gully. This small creek owes its name to the fact that there is a considerable accumulation of black soil filling up the upper portion. The soil has evidently been derived mainly from the decomposition of the serpentine rocks, but also contains numerous small flakes of indurated black slate. Along the serpentine occurrence the black to reddish colour of the soil forms a marked contrast to the barren nature of the Ordovician rocks on either side.

Just above the head of Black Soil Gully there is a lower portion of a spur forming what is generally known as the Monu-

1 Brit. Assoc. Belfast, Sept., 1902.

ment Gap. On both sides of the spur in this vicinity and extending on in a south-easterly direction, the serpentine rocks can be traced. They appear to have been subjected to a considerable amount of mechanical deformation, so that a well defined foliated structure has been induced. The general trend of the planes of foliation is from the north-west to the south-east, and coincides generally with the strike of the Ordovician rocks. Local variations, however, were observed and further on where the chrome iron ore occurs the foliation was more easterly. That the rocks have been subjected to considerable movement, and probably torsion also, is shown by the polishing and slickensiding of the serpentine laminae. Smoothed and rounded boulders were abundant on the slopes of the spur and several were found which showed distinct grooving and striation, and apart from this feature the shape of many of the boulders was even more suggestive of ice action. These boulders were traced to parallel bands in the serpentine, the general features of which are of considerable interest.

The matrix is for the most part serpentine and contains rounded boulders up to six inches and more in length. The included rocks are of various kinds, those noted being, quartzite and other indurated rocks, micaceous schist and basic igneous rock. The boulders of the latter are for the most part either wholly or partially serpentinised. These are the softest rocks in the deposit and are the only ones that showed marked striations. Between the larger boulders, a finer grit is frequently found and the component particles of this portion of the deposit consist chiefly of rounded grains which are now serpentine. Some of the pebbles show distinct evidence of movement in the matrix and consequent slickensliding due to the abrasion by the finer grit. Mechanical deformation is well shown by one of the serpentine boulders which shows a structure similar to that induced by the squeezing of a partially dry ball of putty.

The grooving, and particularly the shape of many of the boulders when examined in the hand specimens, would suggest at once the ice origin of the material, but when the subsequent intense pressure, movement and torsion indicated in the rocks is taken into account the value of striation at any rate becomes less important. It is possible, however, as indicated by the shape of many

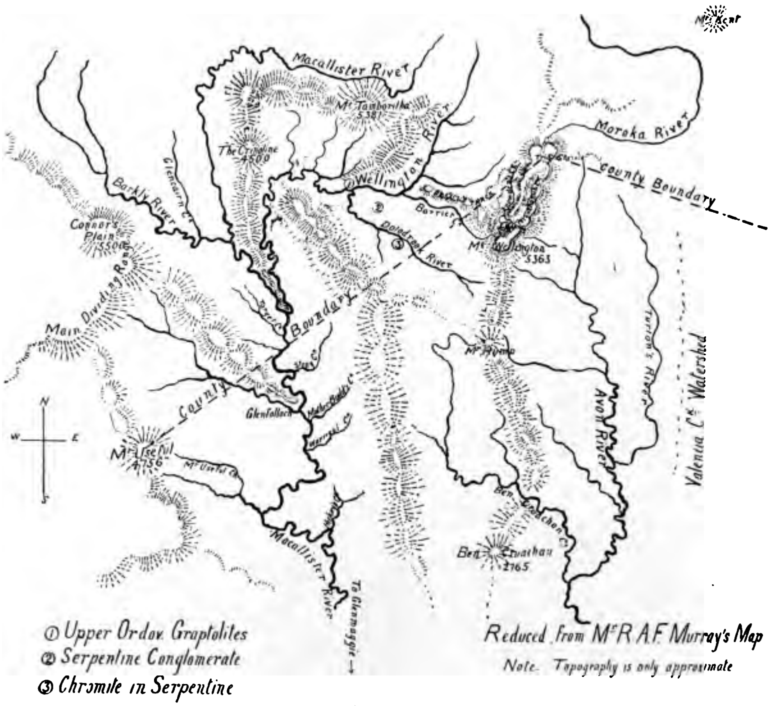
of the included boulders, that glacial action may be the original agency to which the origin of the conglomerate is to be attributed, but both the mechanical and chemical alterations which have taken place make the question a very difficult one to decide at present. The age of this deposit is at present also somewhat obscure, as no sections showing clearly the relation of the conglomerate to the Ordovician rocks or the Upper Palaeozoic series were observed.

Conglomerates are largely developed in the neighbouring Carboniferous rocks, but these differ markedly in lithological features from those of the serpentine area and, further, they usually show little mechanical disturbance.

The general coincidence of the foliation of the serpentine with the prevailing strike of the Ordovician rocks, which here are much folded and broken, points rather to the probability of the serpentine and associated rocks being Ordovician or older.

The conglomerate described appears to present some features quite distinct from those hitherto observed in other conglomerates of Victoria, and some of these are perhaps quite peculiar to this deposit. Serpentine is not a usual matrix of conglomerates; other instances may be known, but in the numerous descriptions of the serpentine occurrences of Great Britain, the Alps and elsewhere, I have been unable to find reference to a conglomerate of this nature.

These few remarks have been written to draw the attention of other geologists to the peculiarities of this deposit, in the hope that some of them may have an opportunity of examining the occurrence more fully and thus aid in solving some of its mysteries.



SKETCH MAP of Mt WELLINGTON DISTRICT

Scale of Miles

[PROC. ROY. SOC. VICTORIA, 18 (N.S.), PT. I., 1905].

ART. II.—*New or Little-known Victorian Fossils in the National Museum, Melbourne.*

PART V.—ON THE GENUS RECEPTACULITES. WITH A NOTE ON R. AUSTRALIS FROM QUEENSLAND.

BY FREDERICK CHAPMAN, A.L.S., &c.,

National Museum.

(With Plates II.-IV.).

[Read 13th April, 1905].

INTRODUCTORY REMARKS.

This paper is devoted to (1) the description of a new species of Receptaculites from the Silurian of Victoria; (2)—the recording of some Victorian Middle Devonian, localities for R. australis, Salter; (3)—the description of certain silicified casts of R. australis collected by the late Mr. Richard Daintree, C.M.G., from the Gympie or Star Beds, Mt. Wyatt, Queensland.

The Devonian specimens of R. australis were originally recorded by Salter as from the Silurian of Australia,[1] and this reference is copied by later authors. The mistake is probably due to the fact that at the New South Wales locality, near Yass, both Silurian and Devonian fossils occur in close proximity, and the two series were most likely mixed by the Rev. W. B. Clarke, who sent the specimens to Salter. In the Molong District, New South Wales, however, R. australis occurs, as Mr. W. S. Dun of the Sydney Department of Mines informs me, in association with Halysites.[2] There is little doubt, therefore, that R. australis did make its appearance in Silurian times, but attained its maximum abundance during the Devonian.

R. australis has formed the subject of a paper by R. Etheridge, junr., and W. S. Dun, in which the structure of the specimens

1 Canadian Organic Remains, Dec. 1, 1859, p. 47.

2 This is probably the fossil recorded by W. B. Clarke (Sed. Form., N. S. W., ed. 4, 1878, p. 16) under the name of R. neptuni, Defr.

from the Middle Devonian of New South Wales is very thoroughly discussed. The examples dealt with by those authors were apparently too fragmentary to afford any precise data for a complete restoration of the external shape of R. australis, for they remark[1] on p. 74:—

"The evidence as to form is by no means conclusive, but seems to support the view of Billings and Rauff that it was in some degree spherical or top-shaped, as against that of Hinde, who regards Receptaculites as a more or less basin or platter-shaped body."

By means of an extensive series of more or less fragmentary specimens of R. australis from Queensland, described in the sequel, we are fortunately able to arrive at a fairly accurate idea of the external form of this interesting fossil.

The occurrence of R. australis in the Middle Devonian limestones of Buchan and Bindi is of especial interest, as affording further proof of the similarity of the fossil contents of those beds with others in New South Wales. Other fossils from Buchan and Bindi, common to Middle Devonian areas in New South Wales, are the various species of Favosites and Syringopora spelaeanus described by Mr. R. Etheridge, junr. Further investigation of the fossils from the Gippsland localities will in all probability afford additional proof of the contemporaneity of these limestones in the two States.

DESCRIPTION OF THE VICTORIAN SPECIMENS.

Genus *Receptaculites*, Defrance.

Receptaculites fergusoni, sp. nov.

(Pl. I., Figs. 1 and 3; Pl. III., Fig. 1).

Description.—This is based on a cast of the lower or outer wall of the sponge, preserved in yellowish, hardened mudstone. Nearly one-half of the sponge is represented, showing the form is funnel-shaped, with indications of a deep central cavity. The surrounding area is broad, depressed and strongly undulated.

The identity of this fossil with Receptaculites is clear, on account of its depressed conical form; as distinguished from

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1 Records of the Geological Survey of New South Wales, vol. vi., pt. i., 1898.

Ischadites, which has a sub-spherical or pyriform body, often concave at the base.

A wax squeeze taken from this fossil cast shows the form of the depressed summit plates, with occasional traces of the diagonal, horizontal, spicular structure. There is also a distinct crenulation on the edges of the summit plates, similar to the figure of the Wenlock specimen of R. ? neptuni Defr., figured by Dr. Hinde.[1]

Measurements.—The present specimen measures 20 mm. in its longest diameter, and probably represents about two-thirds of the entire expanse, or a total diameter of about 30 mm. The rhombic summit plates average 1.5 mm. in their greatest width, and they do not show much variation in size.

Observations.—R. fergusoni shows certain affinities with R. neptuni, Defrance,[2] particularly in the shape of its summit plates and their crenulated margins. It is, however, much smaller than that species, and its conical base not so prolonged.

Occurrence.—In the yellowish hardened mudstone of Silurian age; Wombat Creek, a tributary of the Mitta Mitta River, N.E. Gippsland. From the Mines Department; collected by W. H. Ferguson, after whom the fossil is named [2317].

The above fossil is associated with typical Silurian forms belonging to the genera Euomphalus, Orthis and Atrypa.[3]

Receptaculites australis, Salter.

(Pl. I., Figs. 2, 4, 5, 6, 7; Pl. II.; Pl. III., Figs. 2-7).

Receptaculites australis, Salter, 1859, Canad. Organic Remains, Dec. 1, p. 47, pl. x., figs. 8-10. R. Etheridge, junr., and W. S. Dun, 1898, vol. vi., pt. 1, p. 62., pls. viii.-x.

Observations.—In our Victorian specimens it is the median portion of the sponge wall that is generally seen; the weathering of the fossil producing a regularly papillate surface, owing to the exposure of the ends of the vertical rays or pillars.

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1 Pal. Soc. Mon., vol. xl., 1886 (1887). Brit. Foss. Sponges, pt. i., pl. ii., fig. 3.

2 Dict. Sci. Nat., vol. xlv., p. 5, Atlas, pl. lxviii., fig. 1a-d. See also G. J. Hinde, loc. supra cit., p. 139, pl. ii., fig. 3, pl. iv., fig. 1.

3 For the relationship of the fossiliferous beds, see W. H. Ferguson, in Monthly Progress Rep., No. 3, 1899, Geol. Surv. Vict., p. 17.

These weathered terminals frequently present a rough, rosetted appearance, due to the replacement of the original substance of the pillars by crystalline calcite. The centres of the pillars often contain a residual crystal of calcite towards which the outer and adjacent ones converge, which seems to point to the former existence of a central canal. The calcite crystals surrounding the central area in our specimens sometimes exhibit in transverse section under the microscope a radial grouping of brush-like clusters of fine dark lines, possibly indicative of a previous organic structure as was pointed out by von Gümbel.[1]

Beekite, which was recorded by Etheridge and Dun as occurring in the specimens from New South Wales, has not yet been noticed in our Victorian specimens.

A specimen from Buchan, in grey limestone, shows the rarely occurring actual form of the summit plates of the lower or outer surface of the body-wall of the sponge. On the opposite, weathered face of the same specimen the condition of the pillars shows that they were axially perforated by a slender canal.

The microscopical examination of a number of thin slices of Receptaculites in Middle Devonian limestone, both from Victoria and New South Wales, has revealed isolated and fragmentary horizontal spicules apparently detached from the external layers of the sponge, and distributed through the infilling material or mud forming the black limestone (Plate IV., Figs. 2, 3). These spicules resemble the rest of the sponge-remains in the same beds in being now in the form of calcite. Hinde has remarked[2] with regard to the examples of Receptaculites found in the Trenton Limestone, that, whilst the axial canals are distinctly shown in the siliceous portions of specimens, those parts replaced by calcite have the canals entirely obliterated. One of our specimens, however, which has been replaced by crystalline calcite, shows unmistakable traces of the central canal (Plate IV., Fig. 2). As regards the identity of the spicular body shown on Plate IV., Fig. 3, it may be noted that the space between the two circular prominences

1 Abhandl. k. bayer. Akad. Wiss, 1875, Bd. xii., Abth. i., p. 192.
2 Quart. Journ. Geol. Soc., vol. xl., 1884, p. 810.

exactly corresponds with the distance between the extremities of the vertical pillars of the Devonian examples.

Occurrence.—The Victorian specimens of R. australis came from two localities, Buchan and Bindi, both from the Middle Devonian. The examples from Buchan occur alike in the grey, rather crystalline limestone, and in the black limestone. The specimen in black limestone from Buchan was presented to the Muesum by Mr. G. Sweet, F.G.S. That from the grey limestones was collected by James Stirling, F.G.S., and received from the Mines Department, Melbourne.

The Bindi specimen (Mines Dept., 4113) is in a bluish-grey limestone, weathering brown, and apparently containing a fairly large amount of bituminous matter (anthraconite or stinkstein). This specimen is not mentioned in the general report on the collection by Prof. McCoy (See Progress Report, No. 4, 1877, p. 158).

NOTE ON SOME QUEENSLAND SPECIMENS OF R. AUSTRALIS.

In their "Geology and Palaeontology of Queensland," Messrs. R. Etheridge, junr., and R. L. Jack refer to specimens of a Receptaculites collected by R. Daintree from Mt. Wyatt, but which were afterwards lost sight of. In a note in the abovementioned work, Dr. R. L. Jack writes as follows: [1]"The late Mr. Daintree observed, at Mount Wyatt diggings, certain slates and shales containing Chonetes sarcinulata, an Orthis allied to O. rustica, Receptaculites and Leptaena, as determined by Sir F. McCoy. These rocks were unconformably overlaid by beds, probably of the "Star" series, containing Lepidodendron. On the strength of the fossils, the strata first alluded to were assumed to be of Upper Silurian age. The assumption was based on a single, distinctly specifically determined Brachiopod, Chonetes sarcinulata, now known to range upward into Devonian times, an Orthis, which might be allied to an Upper Silurian species, without being itself of that age—the genus ranging all through the Silurian, Devonian and Carboniferous—a Recep-

1 Geol. and Pal. of Queensland and New Guinea, London, 1892, p. 95.

taculites [every effort has been made, both in London and Brisbane, to trace this fossil, but without success—footnote by R.E., Jun.] and a Leptaena (Silurian and Devonian) not specifically determined. I have not been able to identify the locality referred to by Mr. Daintree, but, as I observed both the Star Beds and the Gympie Beds in the neighbourhood, I think it probable that the Chonetes, etc., beds belong to the latter."

The specimens to which the above reference is made I have lately found amongst the collections of fossils at the National Museum. They were sent by Mr. Daintree to Prof. McCoy on the 7th of September, 1866 (date on box label). The specimens consist of negative replacements of the sponge, in chalcedonic silica, and they agree in their general characters with the better known examples of R. australis from New South Wales. Whether these sponge-bearing beds of Mt. Wyatt belong to the Gympie or to the Star Beds, they, at all events, show an extension of the geological range of this species into beds of Carboniferous age.[1]

Much has already been written on the structure of this sponge, but I venture to add these notes on the Queensland fossils on account of the excellent condition of the casts of the inner and outer layers of the organism. Photographs of the more important examples are included in this paper in order that a comparison of its external features can be made with the excellent figures of the New South Wales Receptaculites given by Etheridge and Dun.

Condition of the Fossils.—The matrix of the bed yielding the Receptaculites is a chalcedonic chert strongly permeated with peroxide of iron. In every case the structure shown by the fossil is a negative one; the outer spicular layer and the rhombic summit plates, however, are so faithfully preserved

1 A few impressions of other fossils occur in the matrix with the Receptaculites. These are referable to Leptaena analoga, Phillips, sp., and the species of Fenestella figured by de Koninck under the name of F. multiporata, McCoy (Descr. Pal. Foss. N.S.Wales, Transl. 1898, p. 134, pl. viii., f. 1, 1a [non 4]). The latter differ from McCoy's Irish specimens, as Mr. Etheridge, Jun., has already pointed out, in the small size and the delicate habit of the zoarium. It is also more divergent in its method of branching. In view of these differential characters, I would propose the specific name Konincki for the Australian specimens. The above-named fossils add no further data for settling the precise horizon of these sponge-bearing beds, as they are found alike in the Star and Gympie series.

that a wax squeeze gives a very detailed impression of the original structure.

When the fossils are sliced vertically, that is, through the outer and inner layers of the wall, and examined microscopically, it is seen that the internal portion with the vertical series of pillars has been absorbed or dissolved during silicification, and, the intervening space being almost entirely filled up by silica, only the bases of the vertical pillars are just discernible in certain places on the cut surface. The internal structure is chiefly visible here and there merely as a ferruginous streak, with patches of partially destroyed spicular structure. In one specimen the form of the spicular mesh has been preserved in iron oxide, which has evidently been the replacing material of the original sponge-structure.

In the case of the Queensland specimens, a siliceous mould has been formed over a pseudomorph, in peroxide of iron, of the spicular layers; whilst in the New South Wales examples the siliceous (beekite) replacement is a positive one, formed on a calcitic base, which latter may have been a replacement of an original siliceous structure.

Form and Dimensions of the Sponge.—R. australis seems to have been typically platter-shaped, widely expanded, with a somewhat thick, slightly upturned rim. The central area was hollowed into a short funnel-shaped cavity, and the base, exteriorly, was slightly prolonged and obtusely rounded. There appears to be no evidence amongst our specimens for the shape suggested by Etheridge and Dun, that is, spherical or top-shaped; the peculiar appearance of the specimen which those authors figure.[1] in which the two walls closely approximate, may possibly be due to distortion or pressure prior to fossilisation.

By the aid of a few more than usually complete examples the general external aspect of this species of Receptaculites may be fairly accurately restored (Plate IV., Fig. 7), and its general dimensions ascertained. A more or less flat expanse of about one-half the disc in one particular specimen gives a breadth of 8 cm., and from this and other similarly derived data we may conclude that the sponge often exceeded 15 cm.

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1 Loc. supra cit., pl. viii., fig. 4.

in diameter.[1] In its vertical height, from the base of the stalk to the level of the rim, this sponge probably measured above 5 cm.

Structure of the Median Layer.—What little remains of the vertical pillars resembles the same structure seen in the organism preserved in the limestone matrix, and is shown by the impressions of the extremities of the pillars taken off the fossils by wax squeezes. The pillars are hollow and constricted near the junction with the outer spicular layers.

Structure of the Upper and Lower Layers of the Body Wall.—The superficial aspect of the Queensland specimens varies according to the particular part of the external layer exposed. Both the summit plates and the underlying spicules in contact with them are clearly seen, and there seems evidence of more than one spicule layer underlying the rhombic plates of the inner or upper surface. So far as can be seen in these specimens, the vertical pillars, constricted near their summits on the inner side of the body wall (endorhin), suddenly expand and give rise to a four-rayed spicular body similar to that shown in the structural diagram of Receptaculites by Billings[2] (Plate IV., Fig. 5).

As previously stated, there is often an intermediate spicule layer between the expanded ends of the pillars and the outer layer of summit plates with their spicular mesh. In this intermediate layer there is a parallel series of fusiform spicules, one end of each spicule being capitate and giving rise to a slender axis turning off at an angle between 90 deg. and 100 deg., and which immediately passes beneath the fusiform spicule-layer. Some approach to this kind of structure is seen in the spicular mesh of Sphaerospongia, an allied genus with hexagonal summit plates, from the Devonian of Devonshire, Germany and Russia.[3]

The external layer is less often seen in our specimens, but when recognisable it shows the sub-rectangular character of the summit plates of the "ectorhin."

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1 The largest specimens figured by Etheridge and Dun from New South Wales also confirm this measurement.

2 Geol. Surv. Canada, Palaeozoic Fossils, vol. i., 1865, p. 382.

3 See Hinde, Pal. Soc. Mon., vol. xl., 1886 (1887). Brit. Foss. Sponges, pt. i., pl. iv., fig. 2c.

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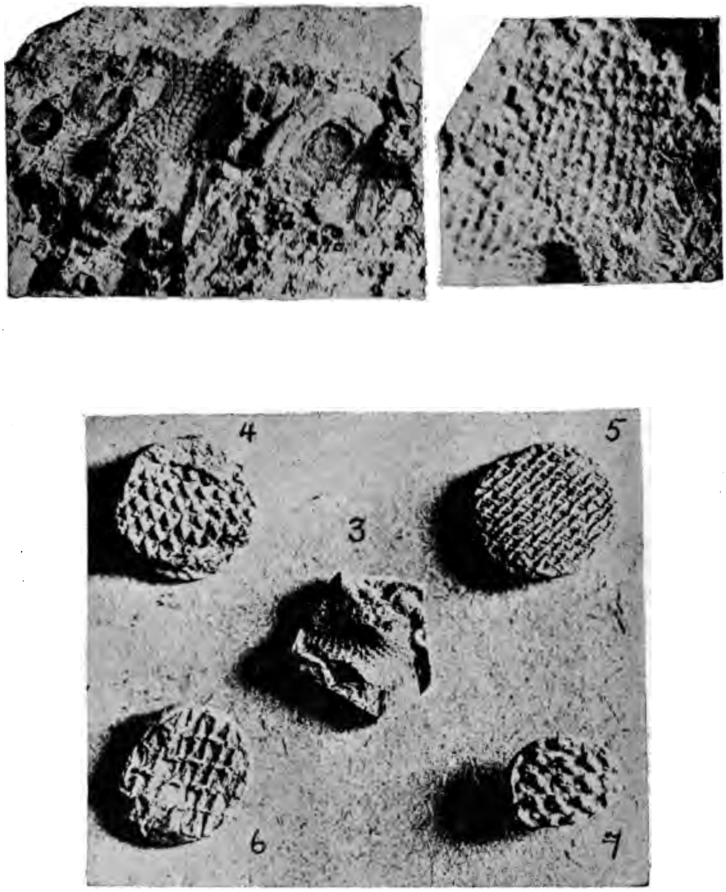


F.C. Photomicr.

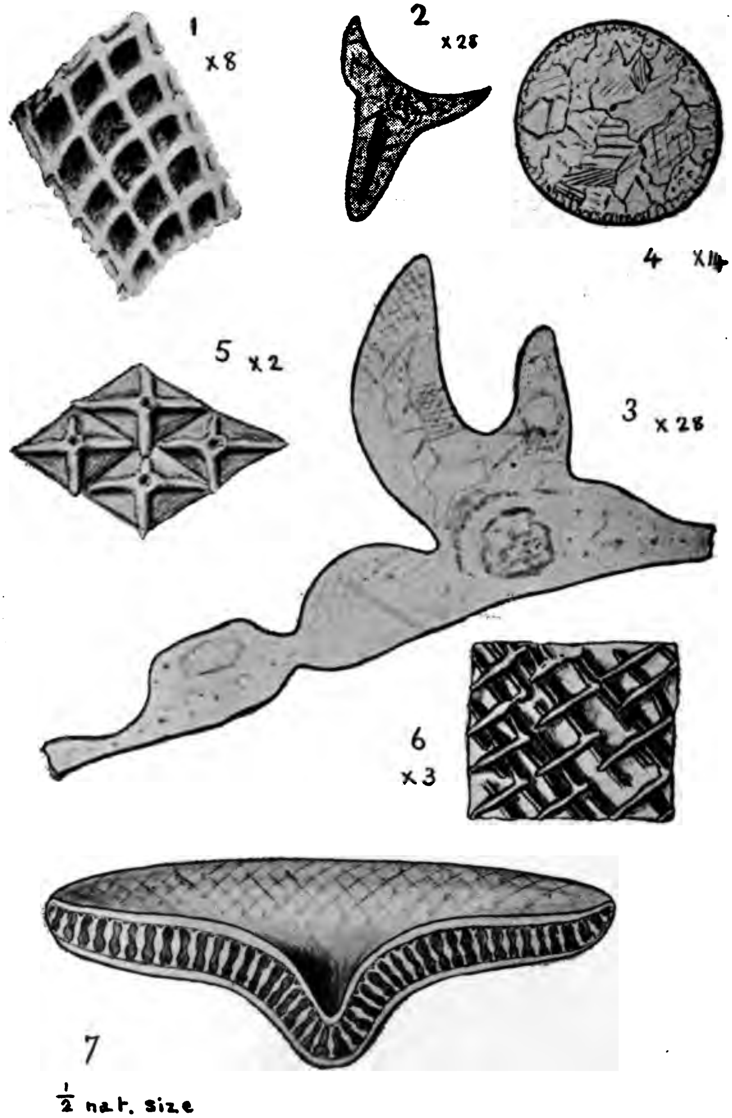
Australian Receptaculites.

1

2

F.C. Photomicr.

Receptaculites—Queensland.



F.C. Del.

Structure of Australian Receptaculites.

SUMMARY.

1. As a genus, Receptaculites ranges from the Silurian to the Carboniferous in Australia. The species R. australis is probably coeval with the genus.

2. The evidence here brought forward with regard to R. australis shows—

(a) The form of the sponge to be sub-discoidal or platter-shaped, with a central funnel-shaped cavity.

(b) The horizontal spicule-rays are apparently derived from, or fused to, the extremities of the vertical rays, at least in the 'endorhin,' and partially so in the 'ectorhin.'

(c) The structure of the horizontal spicular layer shows certain morphological resemblances to that of Sphaerospongia.

(d) The original structure of the Receptaculites from the Mount Wyatt beds, in common with those from Belgium, Silesia and Canada (Hinde) has been pseudomorphosed by peroxide of iron, nearly all of which replacement, in the case of the Australian specimens, has since disappeared, the fossil being represented by a negative cast in silica.

(e) The evidence afforded by the pseudomorphosis of the sponge by peroxide of iron, and its present siliceous epimorphic condition, seems to lend strong support to the idea of an original siliceous structure.

EXPLANATION OF PLATES II.-IV.

PLATE II.

Fig. 1.—Receptaculites fergusoni, sp. nov. Cast of the lower or outer surface of the sponge. Silurian; Wombat Creek, Victoria. [2317]. About natural size.

,, 2.—Lower or outer surface of R. australis, Salter; showing the sub-rectangular form of the summit plates. Middle Devonian; Buchan, Gippsland. [7509]. About natural size.

,, 3.—A wax impression of cast of R. fergusoni, sp. nov.; showing the depressed rhombic summit plates and

the twisted funnel-like form of the sponge. About natural size.

Fig. 4-7.—Wax impressions from the negative siliceous casts of R. australis from Mt. Wyatt, Queensland. Figs. 4 and 7 show the relation of the heads of the vertical pillars to the first layer of horizontal spicules. Figs. 5 and 6 are impressions taken from the horizontal spicular layers. About natural size.

PLATE III.

Fig. 1.—R. australis, Mt. Wyatt, Queensland. A specimen showing negatively the rhombic plates of the inner surface of the cup, and the underlying layer with the heads of the vertical pillars. [7504]. About natural size.

„ 2.—R. australis, Mt. Wyatt. External surface of cup, showing central pedicle and characteristic radial and concentric lines. [7505]. About natural size.

PLATE IV.

Fig. 1.—R. fergusoni, sp. nov. Impression of mud-cast in wax, showing the depressed, rhombic summit plates with crenulated margins; also traces of horizontal spicules. [2317]. x 8.

„ R. australis, Salter. Middle Devonian; Cavan, New South Wales. A bifurcate spicule with trace of axial canal; in calcite. [7516]. x 28.

„ 3.—R. australis. Cavan, New South Wales. Part of a fused spicular layer; in calcite. Found commingled with other fragments of spicular mesh in the matrix, close to the series of vertical pillars. [7516]. x 28.

„ 4.—R australis. Middle Devonian; Bindi, Gippsland, Victoria. A transverse section of a vertical pillar, showing a fine inner circumferential layer of scalenohedra of calcite, succeeded by irregular rhomb-faced crystals of the same mineral. The

dark line may indicate the former existence of an organic membrane. [7515]. x 14.

Fig. 5.—R. australis, Mt. Wyatt. A wax impression from a hollow cast, showing rhombic plates and attached spicules. [7506]. x 2.

„ 6.—R. australis, Mt. Wyatt. A wax impression from a hollow cast, showing the intermediate spicular mesh of the internal surface, with the parallel series of spicules and their slender axial branches. [7506]. x 3.

„ 7.—A restoration of one-half of the cup of Receptaculites australis, Salter, based on the Queensland specimens. The sectional view does not show the spicular layers immediately in contact with the vertical pillars. About one-half natural size.

[PROC. ROY. SOC. VICTORIA, 18 (N.S.), PT. I., 1905].

ART. III.—*New or Little-known Victorian Fossils in the National Museum, Melbourne.*

PART VI.—NOTES ON DEVONIAN SPIRIFERS.

BY FREDERICK CHAPMAN, A.L.S., &c.,

National Museum.

(With Plate V.).

[Read 8th June, 1905].

A NOTE ON THE IDENTITY OF SPIRIFER LAEVICOSTA, MCCOY (*non* VALENCIENNES), WITH S. YASSENSIS, DE KONINCK.

The earliest record of Spirifer laevicosta as a Victorian fossil was given by Selwyn in 1866.[1] In the following year Prof. McCoy wrote[2] regarding the limestone fossils of Buchan, Gippsland, that there was an "abundance of the Spirifera laevicostata, perfectly identical with specimens from the European Devonian Limestone of the Eifel."

The occurrence of this spirifer was subsequently mentioned in two Progress Reports and an Exhibition Essay by McCoy, and it was finally figured and described in the Prodromus of the Palaeontology of Victoria.[3]

In view of the special detailed work on the classification of the brachiopoda published since 1876, giving a better idea of the limitation of specific forms, the publication of these notes may now be opportune.

The Australian species, which has until now been referred to as S. laevicosta (or laevicostata), shows marked specific differences from the S. laevicosta of Europe (Devonshire and the Eifel). It is, however, somewhat allied to the latter species as a Middle Devonian type of spirifer, but is not a typical

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1 Phys. Geogr. and Geol. Vict., p. 10 [Exhibition Essays]; (the specific name was misprinted "*loævicostata*").
2 Ann. Mag. Nat. Hist., ser. 3, vol. xx., 1867, p. 198.
3 Decade iv., 1876, p. 16, pl. xxxv., figs. 2-2b.

ostiolate form (with non-plicate median fold and sinus), since the median fold, in the larger and fully-developed specimens, carries a longitudinal groove.

Points of difference between the European S. laevicosta, Val. and the Victorian S. yassensis, de Kon[1]:—

The specimen which McCoy selected for figuring in the Decades is unusually large,[2] and at a first glance, one acquainted with the European species might see a general resemblance between the two forms.

The Victorian spirifer, however, is sub-ovate in outline, as in the New South Wales specimens, rather than sub-quadrate, as in the European form. The shell is less turgid, the compression also affecting the median fold, which is not so inflated as that of S. laevicosta; there is also a longitudinal groove usually present, especially in the larger Victorian specimens, which is not seen in S. laevicosta. This larger character reminds one of a similar feature in the Devonian S. bifidus, Roemer[3] and the Silurian S. bijugosus, McCoy.[4], The median sinus is narrower and deeper in the central area, and not so acutely V-shaped on the posterior margin of the shell. The shoulders on either side of the beak are steeper and more concave.

The plications are of the same average number in both cases, and show a variation between 11 and 14 counted on either side of the median fold.

The width of the Victorian S. yassensis ranges from 13 to 50 mm.

Spirifer yassensis was first named in MS. by the Rev. W. B. Clarke;[5] and it was afterwards described under the same name by de Konick[6] from specimens obtained from the Devonian limestones of Yass. As I have previously remarked, the New

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1 In this I have had the advantage of comparing a long series of the European S. lævicosta from the Eifel, in the Nat. Mus. Collection.

2 Mr. A. J. Shearsby, of Yass, informs me that he has met with equally large specimen, in the Devonian of Yass, although the fossil is commonly like that figured by de Konick, as regards size. There is also a larger specimen than that figured by McCoy in the collection of the National Museum, from Buchan, presented by C. W. Nicholson (See pl. v., fig. 2, of this paper).

3 Versteinerungen des Harzgebirges, 1843, p. 13, pl. iv., fig. 16.

4 Synopsis Sil. Foss. Ireland, 1846, p. 36, pl. iii. fig. 23.

5 Sedimentary Formations of New South Wales, 1875, 3rd. ed., p. 15.

6 Foss. Pal. Nouv-Galles du Sud, 1876, p. 104, pl. iii., fig. 6.

South Wales specimens, as a rule, are smaller, than those from Victoria; but some of the Buchan specimens are quite as small, being veritable micromorphs, and agreeing in all their characters with the Yass specimens.

Victorian Localities for S. yassensis.—Bindi, head of the Tambo River; Buchan, Murrindal River; and Tabberabbera, at the junction of the Mitchell and Wentworth Rivers.

DESCRIPTION OF SPIRIFER HOWITTI, SP. NOV. (Pl. V., Figs. 4-6).

Shell moderately well-inflated, compressed at the cardinal extremities; sub-quadrate to sub-elliptical, the hinge-line varying in proportion according to length of shell. The chief distinctive characters are the strong plications, 6 to 8 on either side of the median fold; median fold with 2 strong plications, the sinus with two weaker ones, sometimes nearly obsolete; area large; ventral beak much elevated, pointed and only slightly incurved; delthyrium large; dental lamellae well-developed; unweathered specimens show conspicuous, concentric lamellae on the shell surface.

Measurements of three specimens expressed in millimetres:—

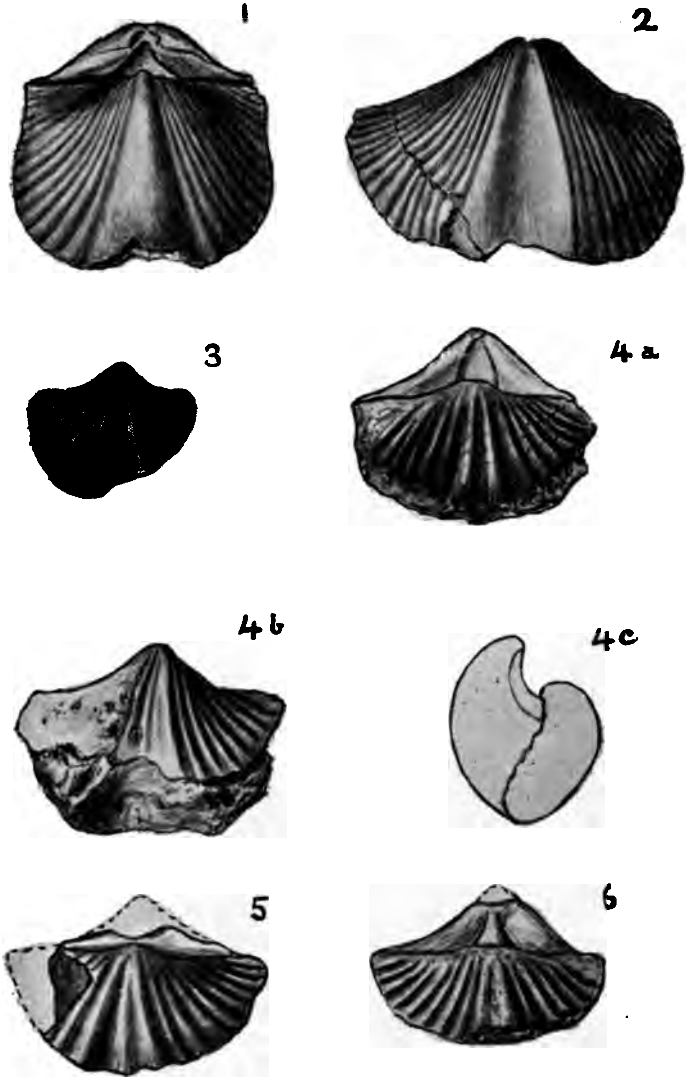
	A.		B.		C.
Length of ventral valve	21.5	-	24.5	circâ	19
Width of shell -	28	circâ	28	circâ	29
Greatest thickness -	15.5	-	23.5	-	15.5
Height of cardinal area	4	-	6.5	-	7

This species falls into the section of the Lamellosi, having a lamellated shell-surface. It apparently belongs to the S. mucronatus type of shell, so far as external characters go, described by Conrad from the Hamilton Group (Middle Devonian) of New York.

S. howitti somewhat resembles in outline S. pittmani, lately described by Mr. W. S. Dun from the Devonian of County Cunningham, New South Wales.[1] That species, however, is one of the ostiolate spirifers, and, further, is more numerously plicated.

Locality.—From the Middle Devonian limestone of Bindi, Gippsland, Victoria. Presented by Dr. A. W. Howitt, by whose

1 Records Geol. Surv. N.S.W., vol. vii., pt. IV., 1904, p. 320, pl. lxi., figs. 4, 4a, b.



F.C. Del.

Devonian Spirifers from Victoria, etc.

efforts the palaeozoic fossil collection of the National Museum has been considerably enriched, and in whose honour the species is named [1232-4]. Also from the Mines Department of Victoria (coll. by W. H. Ferguson). [7596-7.]

A Change in Nomenclature.

In Part II. of New or Little-known Victorian Fossils (this journal, vol. xvi., n.s. pt. 1, 1903, p. 65) the name latior was proposed for a species of Lingula. This name was previously given by McCoy to a Carboniferous species (Brit. Pal. Foss., 1855, p. 475, pl. iii., fig. 33), and therefore the above pre-occupied name must lapse. The new name proposed for this fossil is L. yarraensis.

EXPLANATION OF PLATE V.

Fig. 1.—Spirifer laevicosta, Valenciennes. Middle Devonian, Eifel District. From a specimen in the National Museum.

" 2.—S. yassensis, de Konick. A pedicle valve of a large specimen. Buchan. Pres. by C. W. Nicholson.

" 3.—S. yassensis, de Kon. A pedicle valve of a small shell. Bindi. From Mines Dept. (Coll. W. H. Ferguson.)

" 4.—S. howitti, sp. nov. Mid. Devonian, Bindi. Pres. A. W. Howitt. 4a, type specimen, showing high cardinal area, delthyrium, and lamellose surface of brachial valve; 4b, view of pedicle valve, showing the plicate sinus; 4c, profile aspect.

" 5.—S. howitti, sp. nov. Brachial valve of another specimen, Bindi. From Mines Dept. (Coll. W. H. Ferguson.)

" 6.—S. howitti, sp. nov. Brachial aspect of another specimen (short form), showing traces of the deltidium. Bindi. From Mines Dept. (Coll. W. H. Ferguson.)

[PROC. ROY. SOC. VICTORIA, 18 (N.S.), PT. I., 1905].

IV.—*Victorian Graptolites—Part III.—From near Mount Wellington.*

BY T. S. HALL, M.A.,

University of Melbourne.

(With Plate VI.).

[Read 13th July, 1905].

The small collection of graptolites here dealt with was found by Mr. E. O. Thiele at the junction of the right and left branches of the Wellington River, about six miles west of Mount Wellington. The locality was described briefly by him in a paper on Lake Karng, recently read before the Field Naturalists' Club of Victoria,[1] and also in a paper in the present volume.[2] The country to the south-west and west of Mount Wellington is coloured Silurian [Upper Silurian] on the last issued map of the State, but the fossils here dealt with are of Upper Ordovician age. Graptolites of about the same horizon have been known for some years to occur at Mount Matlock, 35 miles to the north-west, and others have recently been found at the Thomson-Jordan junction, 20 miles west. The area, then, of Ordovician is apparently considerable, though it is all mapped as Silurian. The presence of Monograptus, however, in other beds near the Thomson-Jordan junction show that Silurian [Upper Silurian] rocks are present, so that McCoy's reference of certain beds at Mount Matlock to Silurian [Upper Silurian] on what appeared slender evidence may be quite correct.[3] Mr. Thiele's papers, above referred to, show that the Ordovician transgresses further east into the Upper Devonian (? Carboniferous) area shown on the map. There is evidently room for a good deal of careful mapping in this rugged and

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1 Victorian Naturalist 22, 1905, pp. 22-31.

2 A Palaeozoic Serpentine Conglomerate. Proc. Roy. Soc. Vic., 18, n.s. 1905, p. 1.

3 *See* Whitelaw, O.A.L. The Wood's Point Goldfield. Mem. Geol. Surv. Victoria, No. 3, 1905.

almost inaccessible district, and results of interest may be expected, especially as the presence of Heathcotian is asserted.

The recent publication by the Palaeontological Society of the fourth part of Miss Elles' and Miss Wood's Monograph of British Graptolites, which deals with the Dicranograptidae, renders it possible at last for useful comparisons of our Australian species to be made with those of Europe. The small size and complicated form of the thecae of this group, together with their frequent imperfect condition of preservation, owing to their delicate structure, and their habit of being embedded at all angles in the bedding plane, make their elucidation one of considerable difficulty. The older descriptions and figures were inadequate, but the revision of the authors mentioned makes easy much that was formerly unintelligible.

The specimens which Mr. Thiele has been kind enough to allow me to examine I have identified as follows:—

Diplograptus thielei, n. sp.
Climacograptus wellingtonensis, n. sp.
Cl. bicornis, J. Hall.
Cryptograptus tricornis, Carruthers.
Lasiograptus, sp.
Dicellograptus elegans, Carruthers.
Dicranograptus nicholsoni, Hopkinson.
Dicr. hians, n. sp.

These are clearly of Upper Ordovician age. The descriptions of the previously-named species have been drawn up from specimens in the present collection, no character being dealt with which cannot be seen in them.

Diplograptus thielei, n. sp. (Pl. VI., Fig. 1).

Hydrosome rather broad, the edges gradually diverging from the sicular end. At about 8 or 10 mm. from the sicula, they become parallel, and so continue to the truncate extremity. Sicula nearly one mm. broad at its aperture and one and a half mm. long. Thecae about 4½ times as long as broad, overlapping ⅔ their length. Outer wall of the earlier thecae gently sigmoidally curved. In the later ones it is straight. The earlier thecae have spines about 0.5 mm. long; these decrease in size, and ultimately vanish towards the anti-sicular end.

Length of hydrosome, 15 mm.; breadth, 3 mm.; thecae, 13 in 1 cm., inclined at 40 deg.; apertural margin normal to length of thecae. Virgula distinct, free for 1.5 mm. Virgella lax, 1 or 2 mm. long. Apertural spines of earliest thecae 0.5 mm. An additional spine on the sicular aperture.

This species has a close resemblance to D. carnei, mihi, from New South Wales, but the hydrosome of the latter increases in width continuously. The presence of a free virgula in D. thielei is an additional feature of diagnostic value.

Climacograptus wellingtonensis, n. sp.

(Pl. VI., Figs. 2, 3).

Hydrosome regularly tapering to an acute point. Length, 8-10 mm.; breadth, 0.8 to 1.0 mm. Large specimens may reach a length of 45 mm. and a width of 2 mm., not increasing in width for the last couple of centimeters. Virgula distinct, free for about 1 mm. In young specimens the free virgula may be longer. Virgella as long as the hydrosome. Thecae, 13 in. 10 mm.

The relative lengths of the free virgula and virgella are held to be of prime importance in distinguishing the species of this group, and the species so distinguished are stated by Lapworth to have different ranges in time. There are at the same time slight differences in the form of the hydrosomes. The present species approaches the silurian species C. rectangularis McCoy, more closely than any other.

Climacograptus bicornis, J. Hall.

A single well-preserved example of this species is present, and is of normal form.

Cryptograptus tricornis, Carruthers. (Pl. VI., Fig. 4).

Hydrosome of great tenuity, parallel sided, reaching a length of about 15 mm. and from 1 to 1.5 mm. in breadth. The thecae cannot be distinctly made out nor counted in any of the specimens, but their apertures are distinctly shown by a double series of circular marks, one on each side [illegible]

which is fairly distinct. The virgula is free for about 6 mm. The three spines from which the species takes its name are well marked; in fact, they and the virgula are all that remain of many specimens. Carruthers pointed out the great variation in length in the Scotch examples, and the same curious mixture of different growth stages is found with us. None of the specimens before me show much detail. They are almost too nebulous to draw, and Lapworth says that it was only after the accumulation of much material that he was able to determine the characters which induced him to found the subgenus.[1]

Lasiograptus, sp.

A small fragment 2.5 mm. long apparently belongs to this genus. Four or five thecae are present on each side. The lateral appendages are long and slender, and are connected by a single thread along their distal ends. It occurs on the same slab as about 30 examples of Cryptograptus tricornis and a couple of Climacograptus wellingtonensis.

Dicellograptus elegans, Carruthers. (Pl. VI., Fig. 5).

Branches about 6 mm. long; at first almost parallel, then bending outwards and finally inwards, the shape of the polypary resembling a pair of engineer's callipers. Sicula short and broad, there being no evidence of a virgula or virgella in the only two examples before me. Lateral spines short, but distinct. Thecae apparently about 15 in. 1 cm., but not well enough preserved for accurate counting; their outer walls curved; the apertures turned laterally in deep excavations.

Miss Elles and Miss Wood[2] say that the virgella is always well developed. Its apparent absence in the specimen figured may well be due to imperfect preservation. The thecae in the British specimens are said to number from 8 to 10 in. 1 cm. My estimate of 15 is very doubtful, as only two or three can be seen. The extreme broadening of the distal ends of the branches shown in my figure due to the blurring produced by weathering in the originals

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1 *See* Lapwor p. 171. The name of the sub-
genus is mis

[PROC. ROY. SOC. VICTORIA, 18 (N.S.), PT. I., 1905].

ART. V.—*The Mineralogical Characters of Victorian Auriferous Occurrences.*

BY T. S. HART, M.A., F.G.S.

Lecturer on Geology and Mining, School of Mines, Ballarat.

[Read 13th July, 1905].

The contributions of various authors to the Mineralogy of Victoria have included records of a large number of minerals from the quartz reefs and other auriferous matrices (see especially references 1 to 4 below). In some cases the associations in which the minerals occur are described, and their bearing on the gold-contents noticed. It was early seen that certain minerals were present on nearly all the Victorian goldfields. This prevalence of the one mineralogical type, even in cases where structural features were widely different, has perhaps been one cause of the scantiness of the attention given to the mineralogical characters of the gold occurrences.

In these notes a classification is presented of the mineral associations which are found in our known auriferous matrices and allied mineral deposits. Some occurrences are included which are not proved to be auriferous or whose gold contents are even known to be unimportant, but which occur under conditions analogous to some auriferous lodes or approach them in their characters.

For the basis of the classification I use the predominant minerals among the sulphides, etc., of the ore as unaltered by surface agencies. A bare list of minerals present in any reef or in any field will not adequately represent the character of the ore, as is exemplified by Groups 1 and 2 below. The number of minerals found in a reef is sometimes considerably increased by the minerals noticed in some peculiarly complex patch. Minerals placed below as two distinct groups may be found together in the one reef, though often occurring independently of one another, this is especially the case when the groups ordinarily occur under

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similar conditions. It may also happen that what appears to be one reef may consist of parts of quite different mineralogical types.

The following mineral associations may be recognized, being characterized by the presence or prominence of the minerals mentioned in each case.

1. The ordinary type.—Pyrite or arsenopyrite or both, prominent among the metallic compounds; with sphalerite and galena commonly present in small quantities.
2. Galena and sphalerite prominent with pyrite.
3. Stibnite.
4. Chalcopyrite.
5. Siderite and chalcopyrite.
6. Pyrrhotite and chalcopyrite.
7. Molybdenite usually with pyrite.
8. Bismuth minerals.
9. Wolfram.
10. Cinnabar and mercury.

1. The association of minerals in this type, as ordinarily occurring, may be more fully stated as quartz, albite, dolomite, pyrite, arsenopyrite, galena, gold. Carbonaceous matter is also frequently present, sometimes as graphite.

The albite and dolomite are quite subordinate to the quartz in quantity. The sphalerite and galena, though in much less quantity than the iron minerials, and less generally distributed in the reef, are often persistently present in the richer portions. Of the two iron compounds one or other may be more prominent, or both equally so. The proportion of the metallic minerals in the reef varies greatly. There are of course many reefs of this type from which a part only of the series is recorded.

Dolomite and albite often escape notice in the bad light in the mine, but are easily recognised in most cases by their cleavages. Albite is often altered to kaolin to a considerable depth from the surface, and pholerite also occurs in the cavities of the quartz. Dolomite is often evident on the old material on the mullock heaps, as it contains a little iron carbonate which causes it to turn brown on exposure. In the Ballarat mines it occurs in four forms, impure grey dolomite in the country rock agreeing with

the bedding planes or nearly so; brownish granular masses; veins in the quartz and country rock and patches in the quartz, these show district cleavage; and crystals in the cavities of the quartz. Albite and dolomite are not by any means confined to Ballarat but are widely distributed in occurrences of this type. Albite is less often recorded but this is easily accounted for by its frequent alteration and its less easy recognition.

Carbon occurs in the carbonaceous slates of the country rock, on the walls of the reefs which not infrequently follow the course of these carbonaceous slates, and as the laminations or fine sub-parallel seams in the quartz. In some cases these laminations consist in part of other minerals. Highly lustrous graphite appears to be found chiefly on the planes of movement and in rocks which have undergone more than the usual amount of alteration, as at Stawell and at Piggoreet.

Order of Crystallization.—Cavities containing quartz crystals are not uncommon, and in these we find the quartz often invested by dolomite and pyrite crystals implanted on the dolomite. These crystals are often in pyritohedral forms, whereas in the reefs distinct crystals are not common, and in the country rock they are most commonly cubes. Elsewhere (Dee River, Queensland) we have evidence of gold-nuggets moulded on quartz crystals (7), but the large masses of gold found on the indicator veins are commonly mixed with the vein quartz.

We find, however, evidence of dolomite preceding quartz as well as following it, and pyrite is found enclosed both in quartz and in dolomite.

Crystals of arsenopyrite are found in the country rock at Mt. Pleasant, Ballarat, invested by a thin layer of quartz.

Commonly no growth lines in the quartz are detected nor any crustified character in the reefs. The laminations of the reefs often noticed may be referred to the disposition of the quartz along a series of sub-parallel cracks in the original rock, or in a fault-rock, and the formation of mullocky reefs may be ascribed similarly to deposition on numerous cracks traversing shattered rocks.

We may regard as original the carbonaceous matter of the laminations and probably the grey granular dolomite bands such

as occur at Ballarat East. The pyrite and arsenopyrite of the country rock and the minerals of the reefs may be regarded in the present state of our knowledge as practically contemporaneous. It must, however, be remembered that the quartz reefs of the one field are in some cases of appreciably different ages, as indicated by their relations to one another and to faults. The order of succession in the cavities must not be given too much weight in determining the general process of growth of the reef.

The masses of gold on the indicators should also receive separate investigation from the ordinary reef. To whatever extent the indicator gold may be secondary (whether that term is used with reference to the time of its formation or to its being regarded as subordinate to a general theory of vein formation), it cannot be referred to any process of surface weathering, for these rich patches are associated with easily decomposable minerals, and their characters are continuing unchanged in the deepest levels at Ballarat East.

The mode of association with other minerals and with the quartz also renders impossible any formation by a process of filtration such as recently suggested by one writer (8). Nor can they be due to obstruction to the motion of solutions in view of the nature of the general resistance to the motion of solutions through the fractures and the rocks themselves, for they are in many cases in places where the movement would be easier than usual.

Whatever may have been the sources and the general causes of the deposition of the minerals of the reefs, there is strong evidence that the position of the richer gold contents has been determined by the presence of carbonaceous matter, or at least of certain favourable slates, which are frequently carbonaceous. We find the saddle reefs of Bendigo following the course of carbonaceous beds on which there has been slipping (15). The veins of Ballarat East are often rich in crossing thin carbonaceous beds, and the so-called main reefs of the same field are richest in certain favourable slates. In many localities veins are found along the course of the carbonaceous slates, and richest in their laminated parts. The easiest explanation of the indicator masses seems to be to regard them simply as the extreme case of this more

widespread feature where the favourable bed is most restricted, and the access of the solutions, by a crack nearly at right angles to the indicator, is at the same time facilitated and most definitely localised. Slipping on the carbonaceous bed might then contribute by rendering more easy the percolation of solutions along the beds, providing thus a more ready supply of the active ingredient of these impermeable beds.

Extensions and modifications of the first type. At places in a reef there sometimes appear small quantities of additional minerals. Thus from the Albion Reef, Steiglitz, Ulrich records (2) stibnite, tetrahedrite, and bournonite, with pyrite, sphalerite, gold and pholerite in the hollows of the quartz. The tetrahedrite contains arsenic, iron and zinc. From the Band and Albion Mine, Ballarat, Krausé records (5) calcite, dolomite, siderite with pyrite, chalcopyrite and tetrahedrite. Boulangerite and bournonite have also been recorded from Ballarat, but all these are rare.

Chalcopyrite occurs at a number of localities, according to Mr. R. H. Walcott, more especially Eastern Victorian (4). Mr. H. S. Whitelaw (9) describes the best reefs at Berringa as containing galena and chalcopyrite. It appears to be much commoner there than at Ballarat. Mr. O. A. L. Whitelaw (16), states that the minerals accompanying the lodes at Wood's Point are mainly pyrite and galena, with smaller quantities of sphalerite, copper carbonates and jamesonite. Mr. D. Clark (6) states that in the Cassilis ore, where the sulphides form from 10 to 60 per cent. of the ore, arsenopyrite is most prominent with pyrite, sphalerite, galena, chalcopyrite and small quantities of stibnite and bismuthinite. Magnesium and aluminium silicates are present in this ore. At the Maude and Homeward Bound Mine, Mount Wills, pyrite and arsenopyrite are accompanied by a little stibnite and a silver sulphantimonite.

The Bethanga ore contains the ordinary minerals of the first type of occurrence with the addition of those mentioned below as group 6, chalcopyrite and pyrrhotite, in quantities exceeding the sphalerite and galena (6). The Maldon field gives many examples of the addition of the same two minerals, according to the report of Mr. R. A. Moon (10), with the addition of a variety

of other minerals, more especially those usually found near granitic rocks. Native antimony, stibnite and jamesonite are recorded from this field. A number of the rarer minerals here are found in veins separate from those of the ordinary type as noticed below. A remarkable variation is found near the great vugh of the Eaglehawk Reef, Maldon, the quartz being replaced by cacholong or common opal, in which were garnet, amphibole, ferrocalcite, arsenopyrite, galena and sphalerite.

Indication of gold by the minerals of the reef.—The association of richer portions of the reefs with carbonaceous material has already been noticed. With regard to the minerals of the reef themselves, it is often difficult to get exact information as to their bearing on the gold contents. It remains an open question in many cases whether the greater richness in gold is connected with the appearance of certain definite minerals or with the general increasing complexity of the mixture. An increase in the amount of the sulphides is usually accompanied by increased gold contents.

The appearance of sphalerite or galena in a reef of this type is always regarded as an indication of probably better grade stone. Opinions differ, however, as to which of these is the better, but the balance is in favour of the sphalerite. I have only once heard of an instance in which this mineral was not regarded favourably, and, in this case, the information was not very reliable or complete. It should be remembered that this mineral, being the lightest of the metallic minerals in this type of ore, is less readily saved by the ordinary processes, and its pale and lustreless appearance when crushed renders its loss less easily detected. At Maldon, according to the report already quoted (10), arsenopyrite, sphalerite, and stibnite are regarded as the most favourable to good gold. Pyrrhotite according to the same authority is good in small quantity, but in larger quantity usually bad. Ulrich (1) quotes assays from the wall of the Tiverton Reef, Maldon, as giving from material containing pyrrhotite, 2 to 10 oz. gold per ton.

Arsenopyrite seems to be usually more favourable than pyrite. A sample of slate from Ballarat East, without quartz, but with crystals of arsenopyrite, gave 3 oz. to the ton, and a roughly con-

centrated sample of arsenopyrite from it, 20oz. to the ton. The gold, if not in the arsenopyrite, was at least associated with it.

Mr. H. S. Whitelaw regards chalcopyrite and galena as constantly present in good gold-bearing stone at Berringa (9).

The alteration by surface waters of the minerals of these reefs gives rise to marcasite (which, however, is easily decomposed), melanterite from marcasite, copiapite; limonite; orpiment and realgar very rarely; scorodite probably much more often than recorded, pharmacosiderite, kaolin, pholerite, epsomite, and other minerals.

2. At St. Arnaud, Percydale, and other localities in the Pyrenees there is a great prominence of galena and sphalerite. Accompanying this there is, as might be expected, a larger proportion of silver in the output of the mines. Some parts of the ore yield concentrates which have been smelted for lead. The difference from the preceding type is the great quantity of these minerals which in the ordinary association of minerals are quite subordinate. In some samples of these ores the proportion of quartz also is comparatively small. The general result of assays at Percydale is said to have been that a large amount of galena tended to give high silver contents, and a large amount of sphalerite good gold contents in the ore. An assay at the Ballarat School of Mines of a sample from St. Arnaud containing galena, sphalerite, pyrite and arsenopyrite, with little quartz, gave: silver 19oz. 12dwt., gold 2oz. 19dwt. 11gr. per ton. From the Glendhu Reef, Landsborough, an assay of pyrite is quoted by Ulrich (1) as giving: silver 42oz. 9dwt. 14gr., gold 1oz. 4dwt. 11gr. The material is quoted as an example of pyrite rich in silver. It is not unlikely that it was originally associated with galena, and, if so, may be regarded as analogous to an instance from the Pinnacles, Barrier Ranges, given by Jaquet (11), where a mixture of galena and pyrrhotite had 75 per cent. of its silver in the pyrrhotite, though that mineral without galena was poor or barren.

The galena at Buchan, East Gippsland, where it is found nearly free from sphalerite, seems to contain very little gold. A sample of concentrates from the Buchan Proprietary Mine gave 55 per cent. lead, silver 21oz., gold 3dwt. per ton (12). A quartz

veinstone from Gelantipy quoted in the same report gave, in different samples, up to 71 oz. of silver, but under 4dwt. of gold per ton in the highest assay.

At St. Arnaud bournonite occurs, and in the surface stone anglesite, cerussite, pyromorphite, mimetite, embolite and native copper.

3. Auriferous antimony ores.—Stibnite is only found in small quantities in the ordinary quartz reef, as in the instances already quoted. There are, however, a series of lodes in which it is the leading metallic constituent. These are mainly in the Silurian area of Central Victoria, as at Costerfield and Ringwood, but they are also found in Ordovician rocks, as at Sutton Grange, at Dunolly, and between Ooimaidai and Gisborne. In any question of their origin, then, no importance could be attached to the association with Silurian rocks. Krausé mentions that the Costerfield ore has given assays as high as 9oz. gold and 80oz. silver per ton (5).

The other minerals found with the stibnite are not many nor abundant. Bournonite, cuproplumbite, and chalcostibite are noticed as rare at Costerfield (1). The few occurrences of scheelite in Victoria are not in association with the antimonial ores, though this mineral is found with them at Hillgrove, N.S.W.

Cervantite is the common alteration product of these ores, but kermesite and senarmontite are found in small quantity at a few places, and valentinite somewhat more frequently.

4. Chalcopyrite.—This mineral again is in small quantity in the ordinary type, though it frequently appears with increasing complexity. At the Thompson River Copper Mine it occurs with other copper minerals. A series of assays from this mine (13) showed only a trace of gold, and silver only as high as 6oz. per ton. It is noteworthy that these ores contain up to $3\frac{3}{4}$ per cent. nickel.

While this ore must then be regarded, so far as these assays go, as not a gold producer, it will be seen by examples already quoted that the addition of chalcopyrite to the minerals of the ordinary reef is at least sometimes favourable, though there is nothing to show that the increase in gold is derived from the chalcopyrite.

5. Siderite-chalcopyrite.—A vein composed mainly of these two minerals, with smaller quantities of pyrite, arsenopyrite.

galena and stibnite is described by Ulrich as forming a casing in a claim on the Eaglehawk Reef, Maldon (1). It assayed 17 per cent. copper and 45oz. gold per ton. On occount of the marked difference in the gold contents and the mode of occurrence I place this separate from the Thompson River ore. It approaches most nearly some of the dolomite veins which occur in the first group, but differs in the prominence of chalcopyrite.

6. Pyrrhotite chalcopyrite.—The association of these two minerals with one another is well-known in some important copper-mining localities. In Victoria they often occur in the quartz reefs, but I find no example of their occurrence in important quantity apart from other groups. They appear together as an addition to the groups. At Bethanga the addition of these two minerals to the minerals of the first group produces an ore in which copper is present in important quantity (6). At Maldon the two minerals are recorded by Moon more often from the same mine than separately (10). At Mt. William, in the Grampians, as described below, they occur with the minerals of the next group, but the comparison with mineralogically similar occurrences in the Gong Gong granite near Ballarat indicates that they may be regarded as independent. At the Gong Gong reservoir small quantities of pyrrhotite and chalcopyrite occur in the granite of a small quarry, and molybdenite is found in the same granite a mile away.

Evidence is wanting as to their influence on gold contents of the ore. At Cobar, N.S.W., these minerals with pyrite form the ore worked for copper and carry a little gold, but at a rate which would be worthless where these minerals only themselves form a small quantity of the ore.

The localities of these minerals together are mostly near granitic rocks, or where the rocks are somewhat altered. Pyrrhotite occurs at Piggoreet; here also the rocks are more schistose than usual in the bedrock of the Ballarat district, but the alteration cannot be due to the nearest granite area on the surface, as it is too far away. It seems more likely to be an outcrop of older rocks than usual.

Pyrrhotite occurs at Castlemaine and at Newstead. These also may be not far from granitic rocks.

The next three groups are found in or near the granitic rocks.

7. Molybdenite, usually with pyrite.—At McIntyre's a quartz reef contains these minerals. It is not noticed to be auriferous except on the indirect evidence that the alluvial gold of some gullies appears to start in its vicinity (14). This reef is 100 feet from the ill-defined McEvoy's Reef, from which three masses were obtained in close proximity to one another, and weighing about 800oz. each. Another reef on Mt. Moliagul contains the same two minerals, with the addition of arsenopyrite (14). It may be noticed that arsenopyrite is known as an accessory in the granite rocks at Morang.

At the Mt. William goldfield in the Grampians the gold was largely derived from the neighbourhood of one or more mineralised bands in the granodiorite. Part of the so-called alluvial was simply decomposed granodiorite in situ, carrying fine gold. This led to some remarkable views on the field as to the probable course of supposed deep leads. On these mineralised bands the quartz was in very thin veins for the most part, but at places hollow swellings occurred, lined with quartz crystals of a somewhat amethystine colour. In the alluvial there were many amethyst crystals and quartz crystals with marked zoned structure. The miners stated that the distribution of the gold was about that of the amethysts. Some of the claims worked decomposed seams in the granitic rock and were said to be obtaining payable results. The mineralised bands contained, with these small quartz veins and on joint plane without quartz, molybdenite with a smaller quantity of pyrite, and in some places chalcopyrite and pyrrhotite. Scheelite was also said to occur, but I obtained no certain information on this point. Though the undecomposed rock carrying these minerals was not being worked there can be little doubt that a great part of the gold at least was derived from such occurrences, as gold was being obtained in seams in the partly weathered rock, in thoroughly decomposed rock, and in alluvial, of which some of the characteristic constituents were clearly derived from such bands.

8. Bismuth minerals.—These were noticed by Ulrich from Kingower and elsewhere (1, 2). They occur also at Redbank

near Avoca; among those from this locality there is a little tetradymite. Bismuth minerals with traces of tellurium occur also at Mallacoota (4) and tetradymite is also recorded from Maldon (4). A part of the bismuth at Maldon occurs in the rare mineral maldonite (2). Native bismuth, bismuthinite, bismite and bismutite are recorded from Maldon.

9. Wolfram.—In the localities of which I have most detail this mineral is associated with one of the preceding groups, but it seems best to place it separately. There is no evidence of any influence on gold contents, and it would probably be of more value for itself if in quantity than for its influence on the gold.

The following examples show the minerals of the last three groups associated with one another.

Reef on Sandy Creek, Maldon.—Native bismuth, hematite, schorl and wolfram. No statement as to gold contents (1).

Reef on the Nuggetty Range, Maldon.—Quartz, orthoclase, schorl, mica, molybdenite, wolfram, scheelite. It is contained in granitic rock. Gold is not mentioned (2). Rock crystal and cairngorm occur in the cavities. Reefs of this kind are no doubt the source of the quartz crystals containing, in different instances, molybdenite, scheelite and schorl, which have been found in the neighbouring Bradford Lead.

Superb Reef, Linton, near the granite, contains bismuth, bismuthinite, bismutite, molybdenite, wolfram, besides quartz crystals containing schorl, and rutile (5).

It may be noticed that the supposed columbite at Maldon has been shown to be rutile (4), and that Ulrich records titanium dioxide from Steiglitz (2).

10. The material worked for mercury on the Jamieson River consists, in samples I have received, of a clay rock with quartz veins containing in both cinnabar and mercury. Gold is said to be present. Cinnabar is also recorded from near Bullumwaal, found in small broken fragments on the surface near a quartz reef (4).

Campbell's Reef, Moyston, is mentioned by Ulrich (2) as containing strong irregular veins and patches of calcite, sometimes with galena and pyrite (2). It would seem most likely that these are analogous to the dolomite veins and patches at Ballarat

and other places, and it need not be for this reason separated from the first type.

Manganese oxides are sometimes abundant in the outcrops of quartz reefs. A source of this manganese is not always evident. In some cases, as at Linton, it may be derived from wolfram. Sphalerite may also contribute to it. One analysis of psilomelane from Maldon showed nearly 3 per cent. cobalt oxide. Rhodochrosite is recorded from Clunes (1). A pink mineral in a very thin layer or film is sometimes found at Ballarat, but examination showed neither manganese nor cobalt.

I have in my possession a sample of zinc from Bamganie, said to have been obtained in workings in the 80ft. level of one of the mines. There was nothing in the circumstances under which I obtained it to suggest any doubt as to its genuineness.

I have attempted this classification of the auriferous deposits with a view to arranging the more important parts of our present information, and to suggest a basis for more complete and more systematic observations in the future. Where old records are quoted without any explicit reference they are contained in Atkinson's List of Victorian Minerals (3), and in Walcott's Additions (4). These papers have greatly facilitated the work of this classification.

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END OF VOL. XVIII., PART I.

[PUBLISHED AUGUST, 1905.]

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CONTENTS OF VOLUME XVIII.—PT. II.

[PROC. ROY. SOC. VICTORIA, 18 (N.S.), PT. II., 1905].

ART. VI.—*Catalogue of the Marine Shells of Victoria,* PART IX.; *With complete Index to the whole Catalogue.*

BY G. B. PRITCHARD AND J. H. GATLIFF.

[Read 14th December, 1905.]

The present part includes additional notes and references on the species already referred to by us, together with corrections and alterations, as well as particulars on additional species which have been obtained since the publication of the various parts. The additional species here dealt with number 58, so that with the previous total of 707, our list of Victorian Marine Shells now amounts to 765 species.

An Index to the whole catalogue is appended, giving references to the genera and species, but not to the sub-genera, and we have to thank Mr. R. A. Bastow for its compilation.

We would draw attention to a recent paper by W. H. Dall, entitled "An Historical and Systematic Review of the Frog Shells and Tritons," published by the Smithsonian Institution, Volume xlvii., 1904, pp. 114-144, in which he re-classifies the shells which we have regarded as being comprised in the family Lotoriidae, and refers to some of our species.

ERRATA.

Part	I., p. 238,	line	7,	read 12 for 11.
,,	I., p. ,,	,,	8,	,, 61 for 62.
,,	I., p. 239,	,,	5,	delete Bay.
,,	I., p. 253,	,,	14,	read p. 65, No. 90, for p. 32, No. 4.
,,	I., p. 259,	,,	35,	,, adelaidense for adelaidensis.
,,	I., p. 268,	,,	28,	,, Ranella for Renella.
,,	I., p. 280,	,,	26,	,, 1804 for 1880.
,,	II., p. 185,	,,	2,	,, 12 for 11.
,,	II., p. ,,	,,	3,	,, 61 for 60 and 85 for 83.
,,	II., p. ,,	,,	5,	,, 59 for 58.
,,	III., p. 170,	,,	2,	,, 85 for 83.

Part III., p. 170, line 3, read 59 for 58.
„ III., p. „ „ 4, „ 78 for 77.
„ III., p. „ „ 7, „ 222 for 218.
„ III., p. 190, „ 19, „ Cassis for Carris.
„ III., p. 191, „ 35, „ Abbild for Abh.
„ IV., p. 142, „ 20, „ 1899 for 1889.
„ IV., p. 149, „ 2, „ Angas for Angus.
„ IV., p. 151, „ 29, 30, read Angas for Angus.
„ IV., p. 156, „ 29, read 1887 for 1886.
„ V., p. 121, „ 3, „ 22 for 220 and delete a.
„ V., p. 125, „ 21, „ Gibbula for Gibulla.
„ V., p. 136, „ 10, „ perspectivus for perspectious.
„ VI., p. 197, „ 31, „ Acmaea for Acamea.
„ VIII., p. 236, „ 21, insert Vic. after P.R.S.
„ VIII., p. 238, „ 35, read Jukes' for Juke's,
„ VIII., p. 265, „ 16, „ Shoreham for Storeham.

MUREX DENUDATUS, Perry.

See part i., p. 253.

1811. Triplex frondosa, Perry. Conch, pl. 6, f. 1 (non Murex frondosus, Lam., 1803).
1811. Triplex denudata, Perry. Id., pl. 7, f. 2.
1833. Murex australis, Quoy and Gaimard. Astrolabe Zool., vol. ii., p. 356.
1902. Murex denudatus, Hedley. P.L.S. N.S.W., p. 26.
1902. Murex denudatus, Gatliff. V.N., vol. xix., p 76.
1902. Murex australis, Kesteven. P.L.S. N.S.W., vol. xxvi., part 4, pp. 709-711, pl. 35, f. 10, 11.

Obs.—One of us when recently visiting Paris found that our reference to M. australis, Poirier, should be p. 65, No. 90, instead of p. 32, No. 4.

MUREX ANGASI, Crosse.

See part i., p. 252.

1902. Murex angasi, Kesteven. P.L.S. N.S.W., vol. xxvi., pt. 4, p. 711, pl. 36, f. 6, 7.

TYPHIS SYRINGIANUS, Hedley.

1902. Typhis arcuatus, Pritchard and Gatliff. P.R.S. Vic., vol. x., p. 255.

1903. Typhis syringianus, Hedley. Mem. Aust. Mus., vol. iv., part 6, p. 381, f. 94.

Obs.—In the paper above referred to Mr. Hedley states that our shell is not T. arcuatus, Hinds, which is a South African species.

TROPHON BRAZIERI, T. Woods.

See part i., p. 257.

1900. Trophon brazieri, Hedley. P.L.S. N.S.W., p. 726, f. 23.

TROPHON EBURNEA, Petterd.

See part i., p. 258.

1901. Cantharus eburneus, Tate and May. P.L.S. N.S.W., p. 357, f. 1.

Obs.—In our former remarks on this species, we stated we were not satisfied with the generic position in which it was placed, and we do not think the classification of Tate and May an improvement. The shell measures 16 by 8 mm., is white, fragile, and semi-translucent, their figure quoted might lead one to take it as representing a larger and more robust form.

LOTORIUM RUBICUNDA, Perry.

1811. Septa rubicunda, Perry. Conch., pl. 14, f. 4.

1898. Lotorium australis, Prit. and Gat. P.R.S. Vic., vol. x., p. 262.

Lotorium rubicunda, Gatliff. V.N., vol. xix, p.

LOTORIUM EXARATUM, Reeve.

See part i., p. 265.

Obs.—Mr. Chas. Hedley, P.L.S. N.S.W., 1902, p. 26, considers that Monoplex cornutus, Perry, Conch., pl. 3, f. 1, represents the above species. We do not coincide in this opinion, and Dr. Dall in his paper from the Smithsonian Miscellaneous Collections, vol. xlvii., p. 123, referring to Perry's figures, states: "One, cornutus, Perry, is unidentifiable, certainly not exaratum, Reeve, to which it has been referred."

LOTORIUM SPENGLERI, Chemnitz.

See part i., pp. 263, 264, 265.

1902. Tritonium spengleri, Kesteven. P.L.S. N.S.W., vol. xxvi., pt. 4, p. 713, pl. 36, f. 8, 9.

LOTORIUM (ARGOBUCCINUM) AUSTRALASIA, Perry.

See part i., p. 268.

Lotorium australasia, Perry, displaces L. leucostoma, Lamarck.

1811. Biplex australasia, Perry. Conch., pl. 4, f. 2, 4.

1902. Ranella leucostoma, Hedley. P.L.S. N.S.W., vol. xxvi., pt. 4, p. 631.

1902. Gyrineum australasia, Kesteven. Id., pp. 713, 714, pl. 36, f. 1.

1902. Lotorium australasia, Gatliff. V.N., vol. xix., No. 5, p. 76.

LOTORIUM PARKINSONIANUM, Perry.

1811. Septa parkinsonia, Perry. Conch., pl. 14, f. 1.

1842. Triton fusiforme, Kiener. Icon. Coq. Viv., vol. xvi., p. 36, pl. 5, f. 2.

1844. Triton fusiformis, Reeve. Conch. Icon., vol. ii., pl. 2, f. 16.

1881. Triton fusiforme, Tryon. Man. Conch., vol. iii., p. 11, pl. 4, f. 22.

1902. Tritonium fusiforme, Kesteven. P.L.S. N.S.W., vol. xxvi., pt. 4, p. 712, pl. 35, f. 3-5.

1902. Lotorium parkinsonianum, Gatliff. V.N., vol. xix., p. 76.

1903. Lotorium parkinsonianum, Hedley. Mem. Aust. Mus., vol. iv., pt. 6, p. 340.

Hab.—Cape Everard (E. O. Thiele).

Obs.—This is an interesting addition to our fauna, as showing the southern extension of what has hitherto been regarded as a New South Wales species, as well as being a living survival of a type very abundant in the older Tertiaries of Southern Australia.

FUSUS NOVAEHOLLANDIAE, Reeve.

See part i., p. 269.

Obs.—The type of this species is in the National Museum, Melbourne.

FUSUS UNDULATUS, Perry.

1811. Fusus undulatus, Perry. Conch., pl. 54, f. 1.

1898. Fusus pyrulatus, Pritchard and Gatliff. P.R.S. Vic., vol. x., p. 270.

1902. Fusus undulatus, Gatliff. V.N., vol. xix., p. 76.

FASCIOLARIA AUSTRALASIA, Perry.

1811. Pyrula australasia, Perry. Conch., pl. 54, f. 4.

1898. Fasciolaria coronata, Pritchard and Gatliff. P.R.S. Vic., vol. x., p. 271.

1902. Fasciolaria australasia, Gatliff. V.N., vol. xix., p. 76.

Obs.—Perry's figure represents the form F. fusiformis, Valenciennes.

LATIRUS CLARKEI, T. Woods.

See part i., p. 272.

1901. Euthria clarkei, Hedley. P.L.S. N.S.W., vol. xxv., p. 726, f. 24.

1901. Cantharus clarkei, Tate and May. Id., vol. xxvi., p. 357.

SIPHONALIA DILATATA, Quoy and Gaimard.

See part i., p. 272.

Obs.—The type of Fusus pastinaca, Reeve, is in the National Museum, Melbourne.

PURPURA SERTATA, Hedley.

1903. Purpura sertata, Hedley. Mem. Austr. Mus., vol. iv., part 6. p. 382, 383, f. 95, 96.

Hab.—Port Albert (Thos. Worcester).

PURPURA TRITONIFORMIS, Blainville.

1832. Purpura tritoniformis, Blainville. Nouv. Ann. du Mus., vol. i., p. 221, pl. 10, f. 10.

1898. Cominella (Agnewia) tritoniformis, Pritchard and Gatliff. P.R.S. Vic., p. 275.

1902. Purpura tritoniformis, Kesteven. P.L.S. N.S.W., p. 533-538, pl. 29, f. 2, 3, 5, 7.

Hab.—Western Port, etc.

Obs.—Mr. Kesteven in the above paper deals fully with this shell, and from evidence given by the embryonic form, the radula, and operculum, concludes that it was originally placed by Blainville in the genus to which it correctly belongs.

Genus Truncaria, Adams and Reeve.

TRUNCARIA AUSTRALIS, Angas.

1877. Truncaria australis, Angas. P.Z.S. Lond., p. 172, pl. 26, f. 5.

Hab.—Flinders, Western Port; Port Albert (T. Worcester).

VOLUTA ROADKNIGHTAE, McCoy.

See part i., p. 282.

1901. Voluta roadknightae, Spencer. P. Mal. S. Lond., vol. iv., p. 184.

Obs.—In our previous reference we erroneously stated that the type specimen was obtained at Portland. The shell from that locality exhibited in the National Museum is not the type. In the reference above given Prof. Spencer states: "The type specimen came . . . from Ninety-mile Beach, on the Victorian coast . . . though not in the public exhibition was still preserved in the National Museum." Both of us have been permitted to examine it, and it is beyond doubt the specimen described by Prof. McCoy, the measurements and features given by him exactly corresponding.

MITRA PELLUCIDA, Tate.

1887. Mitra pellucida, Tate. T.R.S. S.A., vol. ix., p. 63, pl. 4, f. 13.

Hab.—San Remo, Western Port.

Obs.—A small, white, pellucid species.

TURRICULA TASMANICA, T. Woods.

See part ii., p. 188.

1903. Turricula tasmanica, May. P.R.S. Tas., p. 109, f. 1, 2.

Obs.—Mr. May in the paper named "On Tenison Woods' types in the Tasmanian Museum, Hobart," gives two figures. Number 1 he considers the typical form. We have not found it here. Number 2 is on the same card as number 1, and is the form we find here.

MARGINELLA PUMILIO, Tate and May.

See part ii., p. 192.

1876. Marginella minutissima, T. Woods. P.R.S. Tas., p. 27 (non Michelin).

1901. Marginella pumilio (nom. mut.), Tate and May. P.L.S. N.S.W., p. 363, pl. 26, f. 79.

Hab.—Brighton (National Museum). Dredged about 7 fathoms, off Rhyll, Western Port.

Obs.—One sinistral specimen also dredged in the last named locality.

MARGINELLA WHANI, Pritchard and Gatliff.

1900. Marginella whani, Pritchard and Gatliff. P.R.S. Vic., vol. xiii., part 1, p. 137, pl. 21, f. 5, 6.

Hab.—Port Fairy (Rev. T. Whan), Carrum Beach, Port Phillip (Thos. Worcester).

MARGINELLA PISUM, Reeve.

See part ii., p. 192.

1865. Marginella pisum, Reeve. Conch. Icon., vol. xv., pl. 27, f. 156.

1877. Marginella (Cryptospira) cypraeoides, T. Woods P.R.S. Tas., p. 122 (non Anton, 1839).

1900. Marginella tenisoni, Pritchard. V.N., p. 55.

1903. Marginella cypraeoides, May. P.R.S. Tas., p. 109, f. 3.

MARGINELLA CYMBALUM, Tate.

1878. Marginella cymbalum, Tate. T.R.S. S.A., p. 87.

1901. Marginella cymbalum, Tate and May. P.L.S. N.S.W., p. 364, pl. 26, f. 83.

Hab.—Port Phillip; Shoreham, Western Port; Portland.

MARGINELLA TRIDENTATA, Tate.

1878. Marginella tridentata, Tate. T.R.S. S.A., p. 87.

1901. Marginella tridentata, Tate and May. P.L.S. N.S.W., p. 363, pl. 26, f. 81.

Hab.—Port Fairy.

MARGINELLA STRANGEI, Angas.

1877. Marginella strangei, Angas. P.Z.S. Lond., p. 172, pl. 26, f. 8.

1902. Marginella strangei, Hedley. P.L.S. N.S.W., p. 18, fig. in text.

Hab.—Port Fairy (Whan).

MARGINELLA SUBBULBOSA, Tate.

1878. Marginella subbulbosa, Tate. T.R.S. S.A., p. 86.

1902. Marginella subbulbosa, Hedley. P.L.S. N.S.W., p 18, fig, in text.

Hab.—Portsea, Port Phillip.

Obs.—Mr. Hedley in the paper above quoted, gives figures of the two foregoing species, and states that they are valid, and Messrs. Tate and May were wrong in uniting them.

MARGINELLA LAEVIGATA, Brazier.

1876. Marginella lavigata, Brazier. P.L.S. N.S.W., p. 225.

1886. Marginella valida, Watson. Chall., vol. xv., p. 267, pl. 16, f. 3.

1901. Marginella laevigata, Hedley. Records Australian Museum, vol. iv., p. 123, pl. 16, f. 5.

1903. Marginella laevigata, Hedley. Memoirs Australian Museum, vol. iv., p. 365, f. 89.

Hab.—Dredged off Rhyll, Western Port, about 7 fathoms.

Genus Pseudamycla, Pace, 1902.

PSEUDAMYCLA D[illegible]ESTOIDEA, [illegible]rck.

182[illegible] [illegible]n, Lamarck. Anim. S. [illegible]5.

[illegible]itchard and Gatliff.

1902. Pseudamycla dermestoidea, Pace. P. Mal. S. Lond., p. 254-257, f. 1-10.

1903. Pseudamycla dermestoidea, Pace. Id., p. 267, 268.

Hab.—Portland, Lorne, Sorrento (Ocean Beach), Port Phillip, Western Port.

Obs.—In the 1902 paper referred to, Mr. Pace enters fully into the history of the confusion regarding this species, which in the first instance had the erroneous locality "West Indies" attributed to it, from the characters of the radula (of which he gives figures), he separates it from the Columbellidae, and makes the shell the type of the above new genus, which he states may be best placed among the Pisaniinae.

PSEUDAMYCLA MILTOSTOMA, T. Woods.

1899. Columbella miltostoma, Pritchard and Gatliff. P.R.S. Vic., vol. xi., p. 200.

1903, Pseudamycla miltostoma, Pace. P. Mal. S. Lond., p. 268.

Hab.—Flinders, San Remo, and dredged off Rhyll, Western Port.

Obs.—Mr. Pace in the paper above referred to, gives full particulars of the appearance of the shell, and the external characters of the animal.

COLUMBELLA SEMICONVEXA, Lamarck.

See part ii., p. 197.

1902. Columbella semiconvexa, Kesteven. P.L.S. N.S.W., vol. xxvii., pt. 1, pp. 5, 6, f. 7.

COLUMBELLA FILOSA, Angas.

1867. Aesopus filosus, Angas. P.Z.S. Lond., p. 111, pl. 13, f. 6. and p. 195, No. 56.

Hab.—Dredged off Rhyll, Western Port, about 7 fathoms.

Obs.—An elongate, spirally lirate species.

Columbella smithi, Angas.

1867. Columbella lentiginosa, Angas. P.Z.S. Lond., p. 195 (non. Hinds).
1877. Columbella smithi, Angas. Id., p. 172, pl. 26, f. 7.
1897. Columbella (Anachis) smithi, Kobelt. Conch. Cab., p. 255, pl. 34, f. 9.

Hab.—San Remo, Western Port.

Obs.—A small species, longitudinally plicate.

Terebra inconspicua, Pritchard and Gatliff.

1902. Terebra inconspicua, Pritchard and Gatliff. P.R.S. Vic., vol. xiv., part 2, p. 181, pl. 9, f. 2.

Hab.—Dredged off Rhyll (about 6 fathoms) and San Remo, Western Port.

Obs.—Larger dead specimens have lately been dredged off Rhyll, measuring length 22 mm., greatest breadth, 8.5 mm.

Terebra fictilis, Hinds.

1844. Terebra fictilis, Hinds. Thes. Conch., vol. i., p. 183, pl. 45, f. 109, 110.
1867. Terebra assimilis, Angas. P.Z.S. Lond., p. 111, pl. 13, f. 8.
1900. Terebra fictilis, Hedley. P.L.S. N.S.W., p. 509, pl. 26, f. 14.
1903. Terebra fictilis, Hedley. Memoirs Australian Museum,, vol. iv., p. 384.

Hab.—Port Fairy (Rev. T. Whan). Dredged 7 fathoms, off Rhyll, Western Port.

Drillia trailli, Hutton.

1873. Pleurotoma trailli, Hutton. Cat. N.Z. Moll., p. 11.
1880. Pleurotoma trailli, Hutton. Man. N.Z., Moll., p. 42.
[illegible] Drillia [illegible] Pritchard and Gatliff. P.R.S. [illegible] part 2, p. 171.

1905. Surcula trailli, Suter. P. Mal. S. Lond., vol. vi., p. 201.

Obs.—Mr. Suter states that the type is in the Colonial Museum, Wellington, N.Z., and beyond doubt the same species as D. aemula, Angas. Tryon, therefore, is right in his treatment of the species, but we are still unable to consider that his two figures correctly represent the same shell. The form, we find, is fairly depicted on his pl. 12, f. 37, as previously quoted by us.

MANGILIA (?) INCERTA, Pritchard and Gatliff.

1902. Mangilia (?) incerta, Pritchard and Gatliff. P.R.S. Vic., vol. xiv., part 2, p. 180, pl. 9, f. 1.

Hab.—Dredged off Rhyll, Western Port.

MANGILIA ST. GALLAE, T. Woods.

1877. Mangelia St. Gallae, T. Woods. P.R.S. Tas., p. 137.

1901. Mangelia St. Gallae, Tate and May. P.L.S. N.S.W., p. 369, pl. 24, f. 33.

Hab.—Dredged off Rhyll, Western Port.

CITHARA KINGENENSIS, Petterd.

See part iii., p. 176.

1879. Daphnella kingenensis, Petterd. Jour. of Conch., vol. ii., p. 102.

1900. Cithara, cognata, Pritchard and Gatliff. P.R.S. Vic., vol. xii., p. 176.

CLATHURELLA DENSEPLICATA, Dunker.

Pleurotoma denseplicata, Dunker. Mal. Blat., vol. xviii., p. 159.

1884. Drillia denseplicata, Tryon. Man. Conch., vol. vi., p. 203, pl. 11, f. 7.

1887. Drillia denseplicata, Kobelt. Conch. Cab., p. 107, pl. 23, f. 7 and 9 only.

1900. Clathurella philomena, Pritchard and Gatliff, P.R.S. Vic., vol. xii., part 2, p. 177.

Hab.—Dredged Western Port.

Obs.—This is the elongated form referred to in the former part of the Catalogue. Tryon gives the length 13 mm.; we have one measuring 17 mm. When living, the shell is suffused with a purple tint.

MITROMORPHA FLINDERSI, Pritchard and Gatliff.

1879. Columbella alba, Petterd. Jour. of Conch., vol. ii., p. 104 (non Jeffreys, 1842).

1897. Columbella (Mitrella) alba, Kobelt. Conch. Cab., p. 288.

1898. Columbella alba, Tate. P.R.S. N.S.W., p. 397.

1899. Mitromorpha flindersi, Pritchard and Gatliff. P.R.S. Vic., p. 104, pl. 8, f. 6.

1901. Mitromorpha alba, Tate and May. P.L.S. N.S.W., p. 372 and p. 455.

Hab.—Western Port.

Obs.—Prof. Tate in the reference above given in a paper on the Fauna of the Older Tertiary of Australia does not state definitely that he considers C. alba, Petterd, to be a Mitromorpha, but says it has a very close resemblance to M. lirata, A. Adams.

Genus **Daphnella**, Hinds, 1844.

DAPHNELLA FRAGILIS, Reeve.

1845. Pleurotoma fragilis, Reeve. P.Z.S. Lond., p. 111.

1845. Pleurotoma fragilis, Reeve. Conch., Icon., vol. i., pl. 21, f. 179.

1846. Pleurotoma lymnaeaeformis, Reeve. Id., pl. 35, f. 325.

1896. Daphnella fragilis, Sowerby. P. Mal., S. Lond., p. 26, No. 10.

Hab.—Dredged off Rhyll, Western Port, about 7 fathoms.

DAPHNELLA MIMICA Sowerby.

1896. Daphnella (Teres) mimica, Sowerby. P. Mal., S. Lond., p. 27, pl. 3, f. 10.

Hab.—Same as the preceding species.

Obs.—We also there obtained the variety fusca, described by Sowerby in the paper above referred to.

DAPHNELLA TASMANICA, T. Woods.

1877. Daphnella tasmanica, T. Woods. P.R.S. Tas., p. 138, No. 19.

1901. Daphnella tasmanica, Hedley. P.L.S. N.S.W., p. 725, f. 21.

1902. Daphnella tasmanica, Hedley. Id., p. 700.

Hab.—Dredged off Rhyll, Western Port, about 7 fathoms.

Genus **Donovania**, Bucq., Dautz., and Dollf., 1883.

DONOVANIA FENESTRATA, Tate and May.

1900. Donovania fenestrata, Tate and May. T.R.S. S.A., p. 94.

1901. Donovania fenestrata, Tate and May. P.L.S. N.S.W., p. 372, pl. 24, f. 36.

Hab.—Flinders, Western Port.

Obs.—Type in Hobart Museum.

CONUS APLUSTRE, Reeve.

1843. Conus aplustre, Reeve. P.Z.S. Lond., p. 171.

1843. Conus aplustre, Reeve. Conch., Icon., vol. i., pl. 30, f. 170.

1858. Conus aplustre, Sowerby. Thes. Conch., vol. iii., p. 32, pl. 205, f. 448.

Hab.—San Remo, Western Port (Mrs. A. F. Kenyon).

NATICA SHOREHAMI, Pritchard and Gatliff.

See part iii., p. 195.

1900. Natica shorehami, Pritchard and Gatliff, P.R.S. Vic., vol. xiii., n. s., pt. 1, p. 131, pl. 20, f. 4.

NATICA TENISONI, Tate and May.

1876. Natica nana, T. Woods. P.R.S. Tas., p. 149 (non Moller).

1900. Natica tenisoni, Tate and May. T.R.S. S.A., p. 94.

Hab.—Flinders, Western Port.

CREPIDULA ACULEATA, Gmelin.

1790. Patella aculeata, Gmelin. Syst., Nat., p. 3693, No. 6.

1822. Crepidula aculeata, Lamarck. Anim., S. Vert., vol. vi., p. 25, No. 3.

1859. Crepidula (Crepipatella) aculeata, Chenu. Man., Conch., vol. i., p. 327, f. 2355, 2356.

1886. Crepidula aculeata, Tryon. Man., Conch., vol. viii., p. 129, pl. 39, f. 61-65.

Hab.—Port Phillip.

Genus Capulus, Montfort, 1810.

CAPULUS VIOLACEUS, Angas.

1857. Capulus violaceus, Angas. P.Z.S. Lond., p. 114, pl. 13, f. 23.

1867. Capulus violaceus, Angas. Id., p. 212, No. 160.

1902. Capulus violaceus, Kesteven. P.L.S. N.S.W., p. 714, pl. 35, f. 7-9.

Hab.—Ocean Beach, Point Nepean; dredged about 7 fathoms, off Rhyll, Western Port.

TURRITELLA SUBSQUAMOSA, Dunker.

1871. Turritella subsquamosa, Dunker. Mal., Blatt, vol. xviii., p. 152.

1900. Turritella oxyacris, Pritchard and Gatliff. P.R.S. Vic., vol. xii., part 2, p. 202.

1900. Turritella lamellosa, Pritchard and Gatliff. Id., p. 203.

1903. Turritella subsquamosa, Hedley. Mem. Austr. Mus., vol. iv., part 6, p. 347.

Hab.—Dredged off Rhyll, Western Port.

TURRITELLA VITTATA, Hutton.

1873. Turritella vittata, Hutton. Cat., N.Z., Moll., p. 29.

1880. Turritella vittata, Hutton. Man., N.Z., Moll., p. 84.

1900. Turritella carlottae, Prit. and Gat. P.R.S. Vic., vol. xii., p. 204.

Obs.—Mr. Suter sends us examples of T. vittata, Hutton, and says it is the same as T. carlottae, Watson.

VERMETUS CAPERATUS, Tate and May.

1900. Thylacodes caperatus, Tate and May. T.R.S. S.A., p. 94.

1901. Thylacodes (?) caperatus, Tate and May. P.L.S. N.S.W., p. 377, pl. 23, f. 14.

1902. Vermetus caperatus, Hedley. Id., p. 19, figures in text.

Hab.—Anglesea.

Obs.—A small brown species, diameter of tube 1 mm.

SCALA MINUTULA, Tate and May.

1900. Scalaria (Acrilla) minutula, Tate and May. T.R.S. S.A., vol. xxiv., part 2, p. 95.

1901. Scalaria minutula, Tate and May. P.L.S. N.S.W., p. 379, pl. 25, f. 41.

1905. Scala minutula, Hedley. Rec. Aust. Mus., vol. vi., p. 52, f. 19.

Hab.—Portsea, Port Phillip; Shoreham, Western Port.

Obs.—A minute brown shell, length given as 2 mm. with five spire whorls. We have specimens before us 3.50 mm. in length with seven spire whorls.

CROSSEA CANCELLATA, T. Woods.

1878. Crossea cancellata, T. Woods. P.R.S. Tas., p. 122. 122.

1882. Delphinula johnstoni, Beddome. Id., p. 31, and 1883, p. 169.

1901. Crosseia cancellata, Tate and May. P.L.S. N.S.W., p. 380, pl. 23, f. 1.

Hab.—Dredged off Rhyll, Western Port, about 7 fathoms.

Genus **Lippistes**, Montfort, 1810.

See part iv., p. 142.

LIPPISTES BLAINVILLEANUS, Petit.

1851. Trichotropis blainvilleanus, Petit. Jour. de Conch., p. 22, pl. 1, f. 5.

1877. Trichotropis tricarinata, Brazier. P.L.S. N.S.W., vol. i., p. 312.

1887. Separatista blainvilleana, Tryon. Man. Conch., vol. ix., p. 45, pl. 8, f. 69.

1899. Trichotropis gabrieli, Pritchard and Gatliff. P.R.S. Vic., p. 183, pl. 20, f. 7.

1899. Separatista blainvilleana, Melvill and Standen. J.L.S., vol. xxvii., p. 169.

1901. Separatista separatista, Hedley. Records Aust. Mus., vol. iv., p. 126, pl. 16, f. 22 (non Dillwyn).

1902. Lippistes separatista, Hedley. P.L.S. N.S.W., p. 23, 24 (non Dillwyn).

Obs.—When we described T. gabrieli it was from a single specimen, which has only two encircling carinae on the body whorl. Other shells have been since dredged in the same locality, and in every instance the body whorl is tricarinate. Examination of the type shows that the growth of the penultimate whorl has been interfered with, and apparently this accounts for its only having two carinae on the body whorl. As Lippistes had not been recorded from our Southern waters, we

concluded it was new. We are now constrained to regard it as an abnormal form of L. blainvilleanus, and are indebted to Mr. C. Hedley for the good work in his papers quoted in clearing up the difficulties surrounding the genus. Since the publication of his paper referred to, he has written to us stating that he now considers L. separatista, Dillwyn, distinct from L. blainvilleanus, Petit, and remarks upon the curious distribution of the species. He dredged it in 10 fathoms off the mouth of the Batavia River, Gulf of Carpentaria, and in 17-20 fathoms, off Masthead Island, Capricorn Group, Queensland. Melvill and Standen record it from Flinders' Entrance, near Mer, 20 fathoms, but there is no record of its occurring in New South Wales or South Australia.

CAECUM AMPUTATUM, Hedley.

1893. Caecum amputatum, Hedley. P.L.S. N.S.W., p. 504, fig. in text.

Hab.—Ocean Beach, Point Nepean.

Genus **Strebloceras**, Carpenter, 1858.

See part iv., p. 144. Caecum, sp.

STREBLOCERAS CYGNICOLLIS, Hedley.

1904. Strebloceras cygnicollis, Hedley. P.L.S. N.S.W., p. 189, pl. 8, f. 12-14.

Hab.—Port Albert (T. Worcester).

EULIMA INDISCRETA, Tate.

See part iv., p. 145.

Obs.—Tate, when describing this species in 1898, draws attention to the fact of E. petterdi, Beddome, being a close ally, and reproduces Beddome's original description, showing points of difference; yet subsequently in Tate and May's Tasmanian Census we find that E. petterdi, Beddome, though described in 1883, is subordinated to E. indiscreta, Tate, as a synonym. This treatment appears somewhat perplexing.

EULIMA TENISONI, Tryon.

See part iv., p. 145.

1901. Eulima tenisoni, Tate and May. P.L.S. N.S.W., p. 380, pl. 25, f. 60, and p. 457.

Obs.—Messrs. Tate and May state that Tryon has figured a shell (referred to by us previously) that is not T. Woods' species; the type of the latter is in the Hobart Museum, and they have named the shell Tryon has figured, E. tryoni.

EULIMA TRYONI, Tate and May.

1886. Eulima tenisoni, Tryon. Man. Conch., vol. viii., non. p. 269, but figure only, 16, pl. 68.

1900. Eulima tryoni, Tate and May. T.R.S. S.A., vol. xxiv., p. 96.

1901. Eulima tryoni, Tate and May. P.L.S. N.S.W., p. 381.

Hab.—Victoria (Tate and May).

EULIMA INFLATA, Tate and May.

1900. Eulima inflata, Tate and May. T.R.S. S.A., p. 95.

1901. Eulima inflata, Tate and May. P.L.S. N.S.W., p. 381, pl. 25, f. 58.

Hab.—Parasitic on starfish dredged off Shoreham, Western Port; (F. E. Grant), dredged off Rhyll; St. Kilda Beach, Port Phillip; (M. Edith Gatliff).

EULIMA ORTHOPLEURA, Tate.

1898. Eulima orthopleura, Tate. T.R.S. S.A., p. 80, pl. 4, f. 1.

Hab.—Port Campbell.

TURBONILLA (ONDINA) HARRISSONI, Tate and May.

1900. Syrnola harrissoni, Tate and May. P.L.S. S.A., p. 96.

1901. Syrnola harrissoni, Tate and May. P.L.S. N.S.W., p. 382, pl. 25, f. 54.

Hab.—Portsea, Port Phillip.

STYLIFER PETTERDI, Tate and May.

See part iv., p. 146.

1884. Stylifer robusta, Petterd. Jour. of Conch., p. 140, No. 22 (non Pease).

1900. Stylifer petterdi, Tate and May (nom mut). T.R.S. S.A., p. 96.

1901. Stylifer petterdi, Hedley. P.L.S. N.S.W., p. 729, f. 27.

STYLIFER LODDERAE, Petterd.

See part iv., p. 147.

1900. Stylifer lodderae, Hedley. P.L.S. N.S.W., p. 92, f. in text.

Obs.—S. marginata, T. Woods (Eulima), is quoted by Tate and May in their Tasmanian Census, p. 381, as replacing the above species, with the remark, however, that the specimen, presumably the type, is "immature and imperfect." May when subsequently dealing with T. Woods' types omits to mention S. marginata.

ODOSTOMIA DEPLEXA, Tate and May.

1900. Odontostomia deplexa, Tate and May. T.S.S. S.A., p. 97.

1901. Odontostomia deplexa, Tate and May. P.L.S. N.S.W., p. 383, pl. 25, f. 45.

Hab.—Flinders, Western Port.

ODOSTOMIA SUPRASCULPTA, T. Woods.

1877. Rissoina suprasculpta, T. Woods. P.R.S. Vic., p. 57.

1900. Odontostomia varians, Tate and May. T.R.S. S.A., p. 97.

1901. Odontostomia suprasculpta, Tate and May. P.[illegible] N.S.W., p. 383, pl. 25, f. 53, and pl. 2[illegible]

Hab.—Portsea, Port Phillip; dredged off Rhyll, W[illegible]

Obs.—The type is in the National Museum.

ODOSTOMIA (PYRGULINA) MAYII, Tate, var.

1898. Odontostomia (Pyrgulina), mayii, Tate. T.R.S. S.A., vol. xxii., p. 84, pl. 4, f. 6.

1902. Odontostomia (Pyrgulina) mayii, Tate and May. P.L.S. N.S.W., vol. xxvi., p. 383.

Hab.—Portsea, Port Phillip.

Obs.—Our shells are rather smaller than the type, and the base differs, otherwise they agree fairly well with the description and figure, so at present we regard it as a variety.

Genus **Oscilla**, A. Adams, 1867.

OSCILLA LIGATA, Angas.

1877. Oscilla ligata, Angas. P.Z.S. Lond., p. 173, pl. 26, f. 11.

1877. Parthenia tasmanica, T. Woods. P.R.S. Tas., p. 150

Hab.—Portsea, Port Phillip; San Remo, and dredged off Rhyll, Western Port.

Genus **Pseudorissoina**, Tate and May, 1900.

PSEUDORISSOINA TASMANICA, T. Woods.

1877. Stylifer tasmanica, T. Woods. P.R.S. Tas., p. 152.

1899. Rissoia tasmanica, Tate. T.R.S. S.A., p. 233.

1900. Pseudorissoina tasmanica, Tate and May. T.R.S. S.A., p. 98.

1901. Pseudorissoina tasmanica, Tate and May. P.L.S. N.S.W., p. 384, pl. 25, f. 55, 56.

Hab.—Portsea, Port Phillip; Flinders and San Remo, Western Port.

BITTIUM MINIMUM, T. Woods.

See part IV., p. 155.

1878. Bittium minimum, T. Woods. P.R.S. Tas., p. 123.

1879. Bittium minimum, T. Woods. Id., p. 35.

1901. Bittium minimum, Hedley. P.L.S. N.S.W., p. 722, fig. 20, in text.

1901. Cerithiopsis minima, Tate and May. Id., p. 385.

Hab.—Western Port; Port Phillip.

Cerithiopsis semilaevis, T. Woods.

1877. Bittium semilaevis, T. Woods. P.R.S. Vic., p. 58.

Hab.—San Remo, Western Port.

Obs.—The type is in the National Museum.

Genus **Seila**, A. Adams, 1861.

Seila attenuta, Hedley.

1900.—Seila attenuata, Hedley. P.L.S. N.S.W., p. 91, pl. 3, f. 9, 9a.

Hab.—Ocean Beach, Point Nepean.

Obs.—When describing this species Mr. Hedley remarks that it is the first record of this genus occurring in Australia.

Triphora granifera, Brazier.

1894. Triforis graniferus, Brazier. P.L.S. N.S.W., p. 173, pl. 19, f. 10.

1903. Triphora granifera, Hedley. Id., p. 610, pl. 33, f. 28, 29.

Hab.—Flinders, Western Port.

Triphora labiata, A. Adams.

1851. Triphoris labiatus, A. Adams. P.Z.S. Lond., p. 279.

1867. Triphoris labiatus, Angas. Id., p. 209, No. 138.

1903. Triphora labiata, Hedley. P.L.S. N.S.W., p. 617, pl. 33, f. 42-44.

Hab.—Shoreham, Western Port.

TRIPHORA CINEREA, Hedley.

1903. Triphora cinerea, Hedley. P.L.S. N.S.W., p. 612, pl. 33, f. 36, 37.

Hab.—Dredged off Rhyll, Western Port.

TRIPHORA MACULOSA, Hedley.

1903. Triphora maculosa, Hedley. P.L.S. N.S.W., p. 614, pl. 32, f. 32, 33.

Hab.—Flinders, Shoreham, and San Remo, Western Port.

Obs.—Mr. Hedley, in the paper above quoted, states that this is the same shell as that known as of A. Adams, under the same name, but the latter never described it, and it was only a list name. He also gives reasons for the adoption of the generic name of Triphora instead of Triforis.

DIALA PICTA, A. Adams.

1861. Diala picta, A. Adams. A.M.N.H., p. 243, and 1862, p. 295.

Hab.—San Remo, Western Port.

Genus **Styliferina**, A. Adams, 1860.

STYLIFERINA, sp.

Hab.—Dredged off Phillip Island, Western Port, about 7 fathoms.

Genus **Callomphala**, Adams and Angas, 1864.

CALLOMPHALA LUCIDA, Adams and Angas.

1864. Neritula (Callomphala) lucida, Adams and Angas. P.Z.S. Lond., p. 35, No. 3.

1899. Teinostoma lucida, Hedley. P.L.S. N.S.W., p. 433, f. 5 (3 in text).

Hab.—Ocean Beach, Point Nepean.

Cyclostrema inscriptum, Tate.

1899. Cyclostrema inscriptum, Tate. T.R.S. S.A., p. 216, pl. 7, f. 3a, 3b.

Hab.—Portsea, Port Phillip.

Cyclostrema johnstoni, Beddome.

1883. Cyclostrema johnstoni, Beddome. P.R.S. Tas., p. 168.

1899. Cyclostrema johnstoni, Tate. T.R.S. S.A., p. 215, pl. 7, f. 7a, 7b.

Hab.—Dredged off Rhyll, Western Port.

Cyclostrema porcellana, Tate and May.

1900. Cyclostrema porcellana, Tate and May. T.R.S. S.A. p. 101.

1901. Cyclostrema porcellana, Tate and May. P.L.S. N.S.W., p. 397, pl. 27, f. 93.

Hab.—Flinders, Western Port.

Cyclostrema angeli, T. Woods.

See part V., p. 100.

1900. Cyclostrema angeli, Hedley. P.L.S. N.S.W., p. 503, pl. 25, f. 14.

Hab.—Western Port.

Lodderia minima, T. Woods.

See part V., p. 101.

1879. Liotia minima, Petterd. Jour. of Conch., vol. ii., p. 88, No. 11.

1900. Lodderia minima, Hedley. P.L.S. N.S.W., p. 94, pl. 3, f. 1-3.

Hab.—Brighton, Port Phillip; Western Port.

Obs.—In Petterd's paper above cited he gives Long Bay, Tasmania, as the locality, seemingly of the type, but the type specimen is, as we have stated, in the National Museum, Mel-

bourne, and the locality given is Brighton. Hedley has since obtained it in Sydney Harbour and in his paper above quoted gives a fuller description of it.

RISSOA AGNEWI, T. Woods.

1877. Rissoa agnewi, T. Woods. P.R.S. Tas., p. 152.

1901. Rissoia agnewi, Tate and May. P.L.S. N.S.W., p. 392, pl. 26, f. 70 (this f. is R. layardi Petterd).

1903. Rissoa agnewi, May. P.R.S. Tas., p. 112, f. 10.

Hab.—Portsea, Port Phillip.

Obs.—Mr. May in the article last quoted states that the fig. No. 70 above referred to represents another species, namely, R. layardi, Petterd.

RISSOA DUBITABILIS, Tate.

1884. Rissoa dubia, Petterd. Jour. of Conch., p. 37 (non Defrance).

1899. Rissoia dubitabilis, Tate (nom. mut.). T.R.S. S.A., p. 232.

1901. Rissoia dubitabilis, Tate and May. P.L.S. N.S.W., p. 391, pl. 26, f. 71.

Hab.—Dredged off Rhyll, Western Port.

RISSOA WOODSI, Pritchard and Gatliff.

1901. Rissoa woodsi, Pritchard and Gatliff. P.R.S Vic., p. 104.

1903. Rissoa woodsi, May. P.R.S. Tas., p. 112, f. 9.

Hab.—Western Port; Port Phillip; Puebla

Obs.—In the paper last referred to, Mr. May agrees with us that it is a distinct species, and gives a figure of it.

RISSOA FLAMMEA, Frauenfeld.

1868. Sabanaea flammea, Frauenfeld. Novara, vol. vi., p. 12, pl. 2, f. 18.

1887. Rissoia (Sabanaea) flammea, Tryon. Man. Conch., vol. ix., p. 339, pl. 63, f. 64.

Hab.—Portsea, Port Phillip.

RISSOA PELLUCIDA, Tate and May.

1900. Rissoia (Nodulus) pellucida, Tate and May. T.RS. S.A., p. 100.

1901. Rissoia pellucida, Tate and May. P.L.S. N.S.W., p. 394, pl. 23, f. 8.

Hab.—Anglesea (T. S. Hall).

Genus **Rissopsis**, Garrett, 1873.

RISSOPSIS MACCOYI, T. Woods.

1877. Rissoa (Ceratia) maccoyi, T. Woods. P.R.S., Tas., p. 154.

1900. Rissoa maccoyi, Hedley. P.L.S. N.S.W., p. 505, pl. 26, f. 11.

1901. Rissopsis maccoyi, Tate and May. Id., p. 394.

Hab.—Flinders, Western Port.

Obs.—The shell somewhat resembles a Truncatella, but may be distinguished from that genus by its spiral sculpture.

LEPTOTHYRA ARENACEA, Pritchard and Gatliff.

See part v., p. 117. Leptothyra, n. sp.

1902. Leptothyra arenacea, Pritchard and Gatliff. P.R.S. Vic., vol. xiv. (n.s.), part 2, p. 181, pl. 9, f. 3.

Hab.—Dredged off Phillip Island, Western Port.

ASTRALIUM FIMBRIATUM, Lamarck.

See part v., p. 117.

1822. Trochus fimbriatus, Lamarck. Anim. S. Vert., vol. vii., p. 12, No. 8.

1844. Trochus squamiferus, Koch. Abbild und Besch, neuer Conch., pl. 4, f. 9.

Hab.—Cape Schanck; Warrnambool. Dredged off Phillip Island, Western Port.

Obs.—Since we previously listed this shell we have obtained the date on which Koch described it, and find that Lamarck's name has priority.

PHASIANOTROCHUS CARINATUS, Perry,

1811. Bulimus carinatus, Perry. Conch., pl. 30, f. 1.
1811. Bulimus eximius, Perry. Id., f. 2.
1902. Phasianotrochus rosea, Pritchard and Gatliff. P.R.S., Vic., vol. xix., p. 125.

Hab.—Western Port, etc.

Obs.—Our species is undoubtedly the same as that figured by Perry.

CALLIOSTOMA HEDLEYI, Pritchard and Gatliff.

See part v., p. 136. Calliostoma, n. sp.

1902. Calliostoma hedleyi, Pritchard and Gatliff. P.R.S. Vic., vol. xiv., part 2, p. 182, pl. 9, f. 4.

Hab.—Western Port, etc.

SCHISMOPE BEDDOMEI, Petterd.

See part vi., p. 181.

1901. Schismope beddomei, Tate and May. P.L.S. N.S.W., p. 407, pl. 24, f. 24.

Hab.—Western Port.

Obs.—This shell is figured for the first time as above quoted.

SCHISMOPE PULCHRA, Petterd.

See part vi., p. 182.

1901. Schismope pulchra, Hedley. P.L.S. N.S.W., p. 726, f. 25.

Hab.—Western Port.

Obs.—Mr. Hedley in the text as above referred to gives a figure of this ornate little species, the dimensions of which are: Diameter, 2 mm.; height, 1 mm.

ACMAEA OCTORADIATA, Hutton.

1873. Patella octoradiata, Hutton. Cat. N.Z., Moll., p. 44.

1903. Patella perplexa, Pritchard and Gatliff. P.R.S. Vic., vol. xv., p. 194.

1904. Acmaea octoradiata, Hedley. P.L.S. N.S.W., p. 188.

Hab.—Port Phillip.

Obs.—Prof. Hutton did not include this species in his Manual, as he doubted whether it was found in New Zealand, but it has recently been obtained there.

Genus **Callistochiton**, Carpenter.

CALLISTOCHITON ANTIQUUS, Reeve.

1847. Chiton antiquus, Reeve. Conch. Icon., vol. iv., pl. 35, sp. 169.

1892. Callistochiton antiquus, Pilsbry. Man. Conch., vol. xiv., p. 274, pl. 59, f. 29-35.

1897. Callistochiton antiquus, Bednall. P. Mal., Soc., vol. ii., p. 150.

Hab.—Port Fairy (Rev. J. Whan); Shoreham.

CHITON CALLIOZONA, Pilsbry.

1894. Chiton (aereus, var.) calliozona, Pilsbry. Nautilus, vol. viii., p. 55.

1897. Chiton calliozona, Bednall. P. Mal. S. Lond., vol. ii., p. 151, figure in text and pl 12, f. 6 a, b, c, d.

Hab.—Obtained within the mouth of the empty shell of a Volute, got off Cape Schanck (R. A. Bastow).

CYLINDROBULLA FISCHERI, Adams and Angas.

See part vi., p. 217.

1903. Cylindrobulla fischeri, Hedley. P.L.S. N.S.W. p. 604, pl. 29, f. 8, 9.

Obs.—This shell is figured for the first time as above quoted.

MACTRA PURA, Deshayes.

See part vii., pp. 105, 106.

Obs.—Actual Victorian specimens of this species have been compared with Deshayes type in the British Museum by Mr. E. A. Smith and one of us, and there is no doubt whatever about their identity.

TELLINA KENYONIANA, Pritchard and Gatliff.

See part vii., p. 118. Tellina, n. sp.

1904. Tellina kenyoniana, Pritchard and Gatliff, P.R.S. Vic., vol. xvii., n.s., pt. 1, p. 339, pl. 20, f. 1-4.

Hab.—Type from Airey's Inlet, odd valves from Rye to Portsea, Port Phillip.

CHIONE NITIDA, Quoy and Gaimard.

1835. Venus nitida, Quoy and Gaimard. Astrolabe, Zool, vol. iii., p. 529, pl. 84, f. 13, 15 (in the text the figures are wrongly given as 13, 14).

1903. Chione fumigata, Pritchard and Gatliff. P.R.S. Vic., vol. xvi., p. 123.

1904. Chione nitida, Hedley. P.L.S. N.S.W., p. 194.

Obs.—We are quite in agreement with Mr. Hedley in his treatment of this species, and the fact of its having been previously overlooked is easily understood, now that he has called attention to the wrong numbering of the figures, and the shell is depicted in such a way as to lead one to consider it as being concentrically ridged, whereas it is concentrically banded, and specimens thus coloured are rarely met with here, as the radial colouration is usually more conspicuous, and frequently all dark markings are absent or only discernible about umbones.

LUCINA MINIMA, T. Woods.

See part vii., p. 138, and p. 139.

1892. Lucina perobliqua, Tate. T.R.S. S.A., vol. xv., pt. 2, p. 128, pl. 1, f. 10.

1903. Lucina minima, May. P.R.S. Tas., p. 114, f. 12.

Hab.—Portsea, Port Phillip; Ocean Beach, Point Nepean.

Obs.—In the last reference given, Mr. May states that there are two species mounted on the card, one of which he figures as being the type, according to description, of T. Woods' species, and the other one he considers to be L. tatei, Angas. Tate and May in their Tasmanian Census united L. minima, and L. tatei. The former species had not then been figured. We now agree with Mr. May in considering them distinct, but they are very similar. May figures a small form, and Tate a very large one.

LUCINA TATEI, Angas.

1878. Lucina tatei, Angas. P.Z.S. Lond., p. 863, pl. 44, f. 15.

Hab.—Coast generally.

Obs.—The sculpture in this species is somewhat coarser than that of L. minima, more especially so in the radial ornament.

Genus **Erycina**, Lamarck, 1804.

ERYCINA ACUPUNCTA, Hedley.

1902. Erycina acupuncta, Hedley. Mem. Aust. Mus., vol. iv., part 5, p. 321, f. 60.

Hab.—Dredged in about 7 fathoms, Western Port, off Phillip Island.

GLYCIMERIS STRIATULARIS, Lamarck.

See part viii., p. 244.

Obs.—In our previous treatment of this species we included P. holosericus, Reeve, as a synonym, based upon the figure and descriptions available to us. In our present examination of specimens from New South Wales of P. holosericus, we note a divergence in the minute details of sculpture, from our ordinary forms of G. striatularis, which, if constant throughout a series, might be utilised for specific distinction.

MYTILUS EROSUS, Lamarck.

1819. Mytilus erosus, Lamarck. Anim. S. Vert., vol. vi., p. 120.

1904. Mytilus polyodontus, Pritchard and Gatliff. P.R.S. Vic., vol. xvii., pt. 2, p. 248.

1904. Mytilus erosus, Hedley. P.L.S. N.S.W., vol. xxix., pt. 1, p. 200.

Obs.—In part viii. of our catalogue above quoted, we refer to the type of M. polyodontus as being in the British Museum collection; these remarks should have been specified as applying to M. menkeanus, Reeve.

Genus **Philippiella**, Pfeiffer, 1886.

PHILIPPIELLA RUBRA, Hedley.

1904. Philippiella rubra, Hedley. P.L.S. N.S.W., p. 207, pl. 10, f. 44-47.

Hab.—Dredged about 7 fathoms Western Port, off Phillip Island; Portsea, Port Phillip; Torquay.

PHILIPPIELLA CRENATULIFERA, Tate.

See part viii., p. 255.

1904. Philippiella crenatulifera, Hedley. P.L.S. N.S.W., p. 208.

Obs.—As the peculiar protoconch of Philobrya is absent in the above shell, Mr. Hedley suggests that it is advisable to place it temporarily as a Philippiella.

INDEX TO GENERA AND SPECIES.

To the respective generic and specific names reference is given to the volume of the Proc. Royal Soc. of Victoria in which it appears, and the page or pages at which they will be found, but for further simplification full particulars of the different parts published are here appended.

Part	I.,	P.R.S.	Vic.,	vol. x. (n.s.), pt. 2, May, 1898, pp. 236–284.
„	II.,	„	„	vol. xi. (n.s.), pt. 2, Feb., 1899, pp. 185–208.
„	III.,	„	„	vol. xii. (n.s.), pt. 2, April, 1900, pp. 170–204.
„	IV.,	„	„	vol. xiii. (n.s.), pt. 1, Aug. 1900, pp. 139–156.
„	V.,	„	„	vol. xiv. (n.s.), pt. 2, April, 1902, pp. 85–138.
„	VI.,	„	„	vol. xv. (n.s.), pt. 2, Feb., 1903, pp. 176–223.
„	VII.,	„	„	vol. xvi. (n.s.), pt. 1, Sept., 1903, pp. 96–139.
„	VIII.,	„	„	vol. xvii. (n.s), pt. 1, Sept. 1904, pp. 220–266.

INDEX.

[PROC. ROY. SOC. VICTORIA, 18 (N.S.), PT. II., 1905].

ART. VII.—*New or Little-known Victorian Fossils in the National Museum, Melbourne.*

PART VII.—A NEW CEPHALASPID, FROM THE SILURIAN OF WOMBAT CREEK.

BY FREDERICK CHAPMAN, A.L.S., &c.,

National Museum.

(With Plates VII., VIII.).

[Read 14th December, 1905].

CONTENTS.

INTRODUCTORY REMARKS.

The subject of the following notes was included in a series of fossils collected by W. H. Ferguson from Wombat Creek, and submitted to Sir Fredk. McCoy for determination by the Mines Department, Melbourne, about April, 1894.[1] The occurrence of this fish is of very great interest, not only on account of its being the oldest recorded vertebrate from Australia, but also that it represents a species of the genus Thyestes, which is by far the largest yet described. The genus Thyestes (=Auchenaspis, Egerton) has, up to the present, been characterized by small-sized species as compared with the fishes belonging to the allied genus Cephalaspis. The specimen now before us vies, in point of size, with the majority of the species of the last-named genus.

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1 I have been unable to find any notes or comments with these specimens.

DESCRIPTION.

Family CEPHALASPIDÆ.

Genus *Thyestes*, Eichwald.

Thyestes magnificus, sp. nov.

Specific Characters.—The remains of this fish available for description consist of more than two-thirds of the dorsal surface of the head shield, together with two and part of a third series of Dorso-lateral plates, which are fused to the shield posteriorly. The fossil is preserved in a limonitic mudstone, and apparently the external layer of the shield and posterior plates is partially dissolved away; but, in spite of this, the surface tuberculations are represented in strong relief. The Cornua are wanting, but there are indications on the matrix that they were incurved and comparatively short.

Head Shield truncately rounded in front and narrower in that region than is usual in the genus. Sides gently rounded and sloping outwards, having a shallow inflection near the middle of the lateral margins. Border of head shield formed by a strong rim, rounded dorsally, whilst just within, on the anterior and antero-lateral margins, lies a series of short, parallel, oblique bars (borders of the marginal cells), cut off by an inner border, bounded in turn by a series of tubercles. The inner border of the head shield leaves the lateral margins at a distance of about 13mm. from the middle of the anterior rim, curving sharply backwards to meet the inter-orbital ridge.

Surface of Shield (Dorsal), originally more or less convex, but now irregular through distortion and slight crushing on the right lateral side; covered with numerous somewhat large tubercles, each seated in a depressed area, usually hexagonal, the sides of which appear to be finely and radiately striate, as in certain figured specimens of Cephalaspis lyelli.[1] The hexagonal tesselation of the shield is best seen in our specimen towards the left posterior angle.

1 cf. Agassiz. Poiss. Foss., vol. ii., pl. 1*b*, figs. 1,2.

It is probable that the tubercles are brought out in stronger relief by the removal of part of the external layer of the shield. Occasionally the tubercles are hollow at their summits, a character likewise observed in certain species of Cephalaspis.[1] A more or less divergent and quincuncial arrangement is observable with regard to the tubercles, and they appear to radiate from near the base of the head shield. There is an obscure areolation of the surface of the shield, due to numerous sinuous ridge-like lines; each areola enclosing several tubercles. The margins of the post-orbital plate are distinctly seen, as well as the inter-obital ridge; the latter is tuberculated on the lateral slopes, rough on the summit, and crenate in front. Position of eyes apparently indicated by a pair of elliptical depressions, situated near the base of the inter-orbital ridge, at a distance of about $\frac{1}{3}$ the length of the shield, measured from the front.

Dorso-lateral scales.—In the known species of Thyestes the fused posterior body scales seem to have been confined to a single series. In our specimen there appear to be some indications of longitudinal junction lines, separating a dorsal and lateral series, but the evidence for such is not so clear as to allow one to speak positively. The lateral edges of the posterior scales extend almost to the base of the cornua.

The surface ornamentation of the dorso-lateral scales is similar to that on the head shield but finer, the tubercles being about $\frac{2}{3}$ the diameter of those on the head shield. The margins of the dorso-lateral scales are strongly scalloped, and in the present specimen do not extend backward so far along the median dorsal ridge as in Thyestes verrucosus, Eichwald.[2]

Dimensions (Approximate, on account of some distortion):—

Length of Head Shield along median line, from anterior rim to the crista occipitalis - - -	39mm.
Width of Head Shield, measured from the widest part at the base of the cornua - - - -	88mm.
Distance of the orbits from the anterior rim of the Head Shield, about - - - - - -	16mm.

1 See "Fishes of the Old Red Sandstone," Powrie and Lankester. Pal. Soc. Mon., vol. xxiii., 1870, p. 55, pl. xiii., fig 19a (C. lightbodii).

2 See Rohon, J. V., "Die obersilurischen Fische von Oesel I." Mem. Acad. Imp. Sci., St. Petersburg, ser. 7, vol. xxxviii., 1892, pl. 1.

Approximate length of Post-orbital Valley - - 18mm.
Greatest longitudinal extent of series of Dorso-lateral scales represented in this specimen - - - 14mm.
Average diameter of tubercles on Head Shield - - 1.5mm.
Average diameter of tubercles on Dorso-lateral scales 1mm.

Affinities.—The present species shows certain affinities to the three known species of Thyestes, viz., T. verrucosus, Eichwald; T. egertoni, Powrie and Lankester sp.,[1] and T. salteri, Egerton, sp.[2] The outline of the head shield, however, is not so long, proportionally, in any of the above-named species, our specimen being more decidedly narrowed in front.

The forward position of the occipital crest corresponds most nearly with that in T. egertoni and T. salteri, T. verrucosus having the crest prolonged far behind the points of the cornua. As regards the post-orbital fossa, the border of its plate in T. magnificus is regularly pyriform or Florence-flask shaped, rather than elongately triangular, as in the restored figure of T. verrucosus given by Rohon,[3] whilst in T. egertoni it is apparently elliptical.

Although our specimen is not sufficiently well preserved to allow one to speak of the actual form of the cornua, the base of the left cornu is so shaped that it seems probable, similarly with T. salteri, they were more prolonged than in T. verrucosus, and recurved towards the body as in T. egertoni, but were not so slender. The tubercles of the head shield are of a uniform size in our species; whilst they are variable in T. verrucosus, and comprise both large and small.

The characters which help to confirm the above described species as belonging to the genus Thyestes are:—

1. The presence of fused posterior dorso-lateral scales.
2. The general form and outline of the head shield.
3. The coarsely tuberculated surface of the head shield, and posterior body scales, comparable to some extent with that of Thyestes verrucosus.

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1 (Auchenaspis egertoni). "Fishes of the Old Red Sandstone." Pal. Soc. Mon., 1870, p. 57, pl. xiii., figs. 3-5; woodcut 30.

2 (Auchenaspis salteri), Egerton. Quart. Journ. Geol. Soc., vol. xiii., 1857, p. 286, pl. ix.

3 Op. cit., pl. 1, fig. 1.

Whilst showing certain characteristics in common with T. verrucosus, T. egertoni, and T. salteri, the species now named T. magnificus differs in the wide, laterally extended, fused posterior elements of the body-covering; in the extremely pronounced tubercular ornament, and the sometimes hollow or perforate character of the tubercles; and in the extraordinarily large size of the head-shield as compared with all known examples of Thyestes. The width ratio of T. magnificus is as 2:1 in comparison with the measurements of a specimen of T. verrucosus given by Rohon[1], and as 4:1 compared with a specimen of T. egertoni in the collection of the National Museum.

Occurrence.—This interesting and unique specimen was found in the Silurian (Yeringian) mudstones of Wombat Creek, a tributary of the Mitta Mitta River, N.E. Gippsland.

At this locality the Silurian rocks rest unconformably on the Upper Ordovician slates and sandstones, the slates of the latter group containing Climacograptus bicornis, J. Hall, var. longispina, T. S. Hall; Dicellograptus elegans, Carruthers; and D. cf. morrisi, Hopk.

The downward succession of these beds, resting on Ordovician strata, is as follows[2]:—

4 Shales and fine-grained sandstone, very fossiliferous—with Trilobites, Crinoids, Corals and Brachiopods. (This bed in all probability yielded the fish remains[3]).

3 Limestone—with Corals and Crinoids.

2 Thin bed of sandstone, with few fossils—Trilobites, Crinoids, Corals, and Brachiopods.

1 Breccia and conglomerate—with internal casts of Atrypa reticularis.

From the general facies of the fossiliferous Silurian rocks exposed at Wombat Creek, it is highly probable that the several beds may all be included in the uppermost or Yeringian series.

A noteworthy feature, in common with similar Silurian rocks of other localities, where the junction of the Silurian and Upper Ordovician can be seen, is the absence of the lower, Melbournian,

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1 Op. supra cit.

2 See Ferguson, W. H. Monthly Progress Report, No. 3, 1889, p. 17.

3 Mr. Ferguson has since confirmed this opinion.

division ; the rocks overlying the Ordovician being apparently in all cases referable to the Yeringian. This affords us unmistakable proof of a remarkable overlap of the upper division of the Silurian system in Victoria, the more extensive development of the upper beds being a consequence of the gentle subsidence of the lower or Melbournian rocks during the deposition of the Yeringian mud, sands and shelly accumulations in the sea which covered central and eastern Victoria during the later Silurian period.

The uppermost beds of the Yeringian series occurring at Lilydale, in the Upper Yarra, near Mount Matlock and at Wombat Creek, contain a few genera (as Panenka, Hercynella[1] and Styliola) which are elsewhere more typical of the rocks of Lower Devonian age, as, for example, the Lower Helderberg series of North America. In regard to the latter, it is somewhat significant that, whilst the European geologists place the L. Helderbergian in the Lower Devonian, the American geologists consider them, together with the Oriskany Sandstone, as the topmost beds of the Silurian, on account of their containing a large percentage of typical Silurian fossils. Our Yeringian beds in Victoria seem to furnish a parallel case, for, although the small admixture of Devonian forms has inclined some geologists to denominate them as Siluro-Devonian, their general facies shows them undoubtedly to belong to the highest beds of the Silurian. A systematic examination of the Yeringian bivalves, which the writer hopes to publish shortly, furnishes further support to the above conclusion.

Judging by the general aspect of the fossils at Wombat Creek, the mudstones of Bed 4 are probably equivalent in part to the Ludlow beds of Shropshire, the Upper Oesel Group in Russia, and the Waterlime Group (and, possibly, the L. Helderberg series) in North America ; whilst the limestone of Bed 3, including the thick limestone bed at Cave Hill, Lilydale, and the lenticular masses of limestone on the Thomson River, contain a facies which reminds one of the Wenlock Group in England and Scandinavia, and of the Niagara Group of North America. In the present imperfect state of our knowledge of the rich Vic-

1 This genus also occurs in the Silurian in the Bohemian basin, but is typically Devonian.

torian Lower Palaeozoic fauna, it is impossible, however, to draw any close comparisons between similar faunas elsewhere; but when this lack of knowledge is supplied, the deductions to be drawn from the data thus afforded, promise, undoubtedly, to be full of interest and value to the stratigraphist.

Associated Fossils at Wombat Creek.—Determinations of a series of fossils from Wombat Creek have already been made by Mr. R. Etheridge, junr., who recorded the following forms[1] :—

Petraia, sp.; Cystiphyllum (probably); a Cyathophylloid coral; Favosites; Pleurodictyum; Alveolites; Heliolites; Plasmopora sp. nov.; (?) Lingula; Leptaena; Strophomena; Orthis; (?) Pentamerus; Rhynchonella decemplicata; Atrypa reticularis; Cromus murchisoni, de Kon.; Phacops.

From the material collected at Wombat Creek, sent to Prof. McCoy, at the National Museum, I have myself made the following determinations of Yeringian fossils:—Receptaculites fergusoni, Chapm.; Amplexus sp.; Favosites sp. nov.; Encrinurus punctatus, Brünnich, sp.; E. murchisoni, de Kon. sp.; Rhombopora sp. nov.; Chonetes cresswelli, Chapm.; C. striatella, Dalman sp.; (?) Stropheodonta sp.; Orthis testudinaria, Dalman; Atrypa reticularis, Linn. sp.; Atrypina imbricata, Sow. sp.; Spirifer plicatellus, Linn. sp.; (?) Spirifer sulcatus, Hisinger sp.; Cyphaspis sp. nov.; Thyestes magnificus, sp. nov.

EXPLANATION OF PLATES.

PLATE VII.

Thyestes magnificus, sp. nov.

Part of Head-Shield and Dorso-lateral scales. Surface of fossil somewhat decorticated. In Silurian (Yeringian) mudstone, Wombat Creek, N.E. Gippsland. Natural size.

PLATE VIII.

Fig. 1.—Restoration (diagrammatic) of Thyestes magnificus, sp. nov. Explanation of lettering:—*a.r.*: antor-

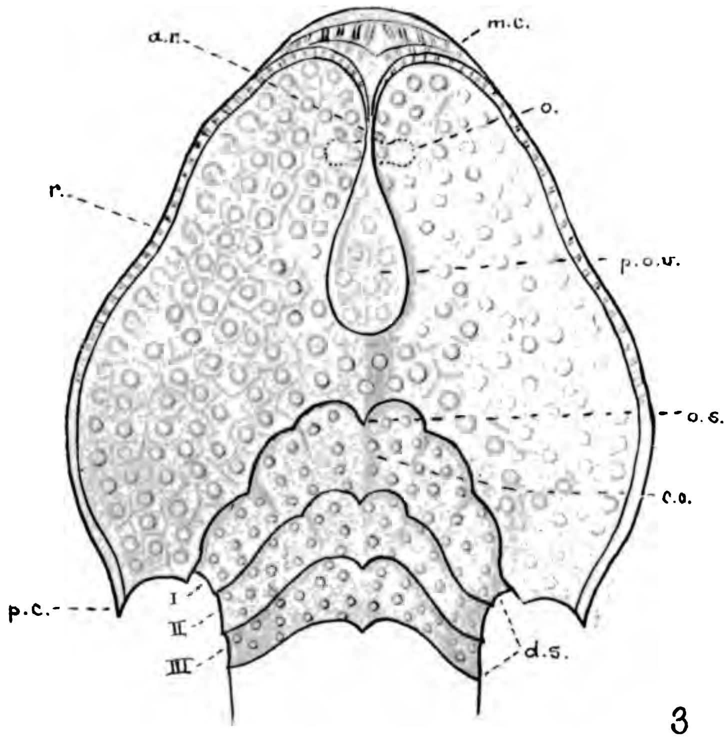
1 Prog. Rep., vol. x., 1899, pp. 100, 101.

bital ridge; *c.o.*: occipital crest; *d.s.*: dorso-lateral scales; *m.c.*: marginal cells; *o.*: probable position of orbit; *o.s.*: occipital spine; *p.c.*: posterior cornu; *p.o.v.*: post-orbital valley; *r.*: rim.

Fig. 2.—T. magnificus, sp. nov. Hexagonal markings of Head-shield, surrounding tubercles; seen on left posterior region of shield. × 2.

" 3.—T. magnificus, sp. nov. Portion of the left anterior margin of shield, above the rounded lobe; showing the form of the marginal cells. × 2.

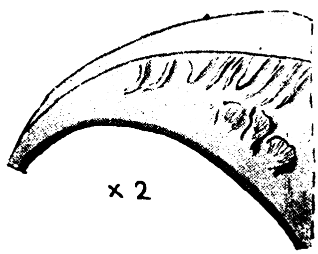
1



2

× 2

3



× 2

ANNUAL REPORT OF THE COUNCIL

FOR THE YEAR 1904.

The Council of the Royal Society herewith presents to the Members of the Society the Annual Report and Statement of Receipts and Expenditure for the year 1904.

Meetings were held as follows :

March 10.—Annual Meeting and Election of Officers. Ordinary Meeting. *Exhibits :* 1. Moa Feathers, by Professor W. Baldwin Spencer. 2. Some curiously-grown shells and casts of shells in gypsum, by F. Chapman—on behalf of the Trustees of the National Museum. 3. Spinthariscope, by Professor W. C. Kernot.

April 21—Special Meeting in conjunction with the Field Naturalists' Club, at which the Mueller Medal, awarded by the Australasian Association, was formally handed over to Mr. A. W. Howitt.

May 12.—*Papers :* 1. "Contributions to our knowledge of the Anatomy of Notoryctes typhlops," by Dr. Georgina Sweet. 2. "Relations of the Granite and Silurian Rocks of Dandenong," by J. M. Sutherland. *Exhibits :* Two rare Birds of Paradise, Pteridophora alberti and Aslaphia nigra (male), by J. A. Kershaw—for Trustees of National Museum.

June 9—*Papers :* 1. "The Alternate Current Transformer," by Professor T. R. Lyle. 2. "Revision of the Australian Aphodiides," by Rev. T. Blackburn. 3. "Tabulated List of the Fossil Cheilostomatous Polyzoa in the Victorian Tertiary Deposits," by C. M. Maplestone. 4. "The Antiquity of Man in Victoria," by Professor J. W. Gregory.

July 14.—*Papers :* 1. Catalogue of the Marine Shells of Victoria, Part 8," by G. B. Pritchard and J. H. Gatliff. 2. "Contributions to the Palaeontology of the Older Tertiaries of Victoria—Gastropoda, Part 2," by G. B. Pritchard. 3. "Tertiary Fish of Australia, Part 1," by F. Chapman and G. B.

Pritchard. 4. "New or Little-known Victorian Fossils in the National Museum, Melbourne, Part 4—Some Silurian Ostracoda and Phyllopoda," by F. Chapman. 5. "Description of Some New Victorian Mollusca," by G. B. Pritchard and J. H. Gatliff.

August 11.—*Paper:* "The Mount Morgan Goldfield," by E. J. Dunn. *Exhibits:* 1. Sections of Wood showing Drought Registering, by E. J. Dunn. 2. Fibre-balls from Middleton Beach, near Goolwa, South Australia, by J. A. Kershaw—for the Trustees of the National Museum. 3. Spear Throwers from Cape York and German New Guinea, by H. R. Walcott—for the Trustees of the Museum. 4. Palaeospondylus gunni, by F. Chapman—for the Trustees of the Museum.

September 8.—*Paper:* "A Crab from the Victorian Tertiaries (Ommatocarcinus corioensis, Cresswell, sp.), by T. S. Hall. *Exhibits:* 1. Skull of Gilbert Islander, cut by bamboo knife; also Bamboo Knife from New Guinea, by Professor W. Baldwin Spencer. 2. Skull of adult Female Australian Aboriginal from the Geelong district with clear frontal suture, by Professor W. Baldwin Spencer. 3. Teeth and symphysis of lower jaw of Diprotodon australis from Lake Calvert, by Biological Department of University. 4. Specimens in illustration of his paper, by T. S. Hall.

October 13.—*Papers*: 1. "On Nepharis and other Ant's-nest Beetles, taken by J. G. Goudie, at Birchip," by A. M. Lea. 2. "Note on the Stony Creek Basin, Daylesford," by T. S. Hart. 3. "Account of the Separation and Identification of a Kaolin Incrustation on Pyrolusite, from Broken Hill," by G. S. Walpole.

November 10.—*Papers*: 1. "Polyzoa from Lord Howe Island," by C. M. Maplestone. 2. "Notes on the Older Tertiary Foraminiferal Rocks of Santo, New Hebrides," by F. Chapman (withdrawn). 3. "On the Occurrence of the Genus Cryptoplax in the Victorian Tertiaries," by T. S. Hall. *Exhibit*: "Volcanic Dust gathered from the deck of the 'Roddam,' Bay of S. Pierre, 8th May, 1902," by F. Chapman.

December 8.—Mr. G. Sweet delivered a Lecturette, entitled, "Recent Geological Changes in the Atoll of Funafuti," illustrated by Lantern Slides.

During the year two Members, one Country Member, and four Associates were elected, and two Members and one Associate resigned.

The "Proceedings" of the Society, New Series, Vol. XVI., Pt. 2, and Vol. XVII., Pt. I., were published during the year.

A deputation of the Council waited on the Chief Secretary during the year, to request an increase in the Annual Grant, but the Council was disappointed to find that no increase was made. The increased size of the volume has meant a larger expenditure, and our finances are consequently at a very low ebb. The sum which was originally specially collected as a Research and Publication Fund, has, during the past few years, become exhausted, and unless the Government come to our aid to assist us in publishing the results of the investigations of our members, our annual volume must be materially diminished in size, and a great deal of valuable matter will be lost. A further appeal will be made to the Government during the year, when it is hoped that the requisite amount will be granted.

During the year the Library was increased by the addition of 1112 volumes and parts. The binding is getting still further into arrears, and valuable publications, not found elsewhere in the State, are in danger of being destroyed.

It is desirable that the grounds and fencing should be put in better order, and the caretaker's cottage is also in urgent need of repairs, but the work is at present beyond our means.

The Honorary Treasurer in Account with the Royal Society of Victoria.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance from 1903	£55	18	4	By Printing and Stationery .. .	£247	17	7
Government Grant	50	0	0	Postages	25	10	7
Subscriptions—				Freight, Advertising and Sundries	4	17	11
Members	57	15	0	Salary of Assistant-Secretary	25	0	0
Country Members	3	3	0	Custodian	6	0	0
Associates	26	5	0	Rates	5	13	4
Arrears	24	3	0	Insurance	5	1	3
Rent of Rooms	7	15	0	Repairs	3	7	6
Interest	6	0	0	Sewerage Connections	6	10	2
Sale of Publications	12	6	6	Books and Periodicals	5	15	9
Transfer from Publishing Fund ...	200	0	0	Furniture	1	8	6
				Collector's Commission	10	0	0
				Gas and Fuel	5	6	5
				Refreshments	6	2	9
					£358	11	9
				Balance	84	14	1
	£443	5	10		£443	5	10

Compared with the Vouchers and Bank Pass-Book, and found correct,

(Signed) P. DE JERSEY GRUT,
Hon. Treasurer.

(Signed) H. MOORS,
JAMES E. GILBERT, } *Auditors.*

7th March, 1905.

Royal Society of Victoria.

1905.

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1905.

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His Excellency Sir Reginald Talbot, K.C.B.	1904

Honorary Members.

Forrest, The Hon. Sir J., K.C.M.G., West Australia ...	1888
Hector, Sir James, K.C.M.G., M.D., F.R.S., Wellington, N.Z.	1888
Liversidge, Professor A., LL.D., F.R.S., University, Sydney, N.S.W.	1892
Neumayer, Prof. George, Ph.D., Hamburg, Germany ...	1857
Russell, H. C., B.A., F.R.S., F.R.A.S., Observatory, Sydney, N.S.W.	1888
Scott, Rev. W., M.A., Kurrajong Heights, N.S.W. ...	1855
Todd, Sir Charles, K.C.M.G., F.R.S., Adelaide, S.A. ...	1856
Verbeek, Dr. R. D. M., Buitenzorg, Batavia, Java ...	1886

Life Members.

Butters, J. S., F.R.G.S., Empire Buildings, Collins-street west	1860
Eaton, H. F.	1857
Fowler, Thos. W., M.C.E., University, Melbourne ...	1879

Gibbons, Sydney, F.C.S., 31 Gipps street, East Melbourne. 1854

Gilbert, J. E., "Melrose," Glenferrie-road, Kew 1872

Love, E. F. J., M.A., F.R.A.S., 213 Victoria Terrace, Royal Park 1888

Nicholas, William, F.G.S. 1864

Rusden, H. K., Glenhuntly-road, Elsternwick 1866

Selby, G. W., 99 Queen Street, Melbourne 1881

White, E. J., F.R.A.S., Observatory, Melbourne ... 1868

Ordinary Members.

Balfour, Lewis, B.A., M.B., B.S., Burwood-road, Hawthorn 1892

Baracchi, Pietro, F.R.A.S., Observatory, Melbourne ... 1887

Barnes, Benjamin, Queen's Terrace, South Melbourne ... 1866

Bavay, A. F. J. de, Foster Brewery, Collingwood ... 1905

Berry, Wm., Normanby-road, Kew 1898

Boese, C. H. E., 159 Hoddle-street, Richmond 1895

Boys, R. D., B.A., Public Library, Melbourne 1903

Cherry, T., M.D., M.S., Department of Agriculture, Melbourne 1893

Cohen, Joseph B., A.R.I.B.A., Public Works Department, Melbourne 1877

Chapman, F., A.L.S., National Museum, Melbourne ... 1902

Dennant, John, F.G.S., F.C.S., Stanhope-grove, Camberwell 1886

Dunn, E. J., F.G.S., "Roseneath," Pakington-street, Kew 1893

Ellery, R. L. J., C.M.G., F.R.S., F.R.A.S., Observatory, Melbourne 1856

Field, W. E., 65 Sutherland-road, Armadale 1903

Fox, Dr. W. R., L.R.C.S., L.R.C.P., "York House," Brunswick-street, North Fitzroy. 1899

Fryett, A. G., care Dr. F. Bird, Spring-street, Melbourne 1900

Gault, Dr. E. L., M.A., M.B., B.S., Collins-street, Melbourne	1899
Gillott, The Hon. Sir S., K.C.M.G., M.L.A., "Edensor," Brunswick-street, Fitzroy	1905
Grut, P. de Jersey, 125 Osborne Street, South Yarra ...	1901
Hake, C. N., F.C.S., Melbourne Club, Melbourne ...	1890
Hall, T. S., M.A., University, Melbourne	1890
Hartnell, W. A., "Irrewarra," Burke Road, Camberwell	1900
Harvey, J. H., A.R.V.I.A., 128 Powlett-street, East Melbourne	1895
Heffernan, E. B., M.D., B.S., 10 Brunswick-street, Fitzroy	1879
Hogg, E. G., M.A.	1890
Hooper, Dr. J. W. Dunbar, L.R.C.S., etc., Collins-street, Melbourne	1904
Howitt, A. W., F.G.S., D.Sc., "Clovelly," Metung ...	1877
Howat, Wm., 458 William-street, Melbourne	1903
Jamieson, James, M.D., 96 Exhibition-street, Melbourne	1877
Jenkins, H. C., A.R.S.M.	1899
Kernot, Professor W. C., M.A., M.C.E., University, Melbourne	1870
Kershaw, J. A., F.E.S., National Museum, Swanston-street	1900
Kitson, A. E., F.G.S., Department of Mines, Melbourne	
Lyle, Prof. T. R., M.A., University, Melbourne ...	1889
Loughrey, B., M.A., M.D., Ch.B., M.C.E., 1 Elgin-street, Hawthorn	1880
Masson, Professor Orme, M.A., D.Sc., University, Melbourne	1887
Michell, J. H., M.A., F.R.S., University, Melbourne ...	1900
Moors, H., 498 Punt Road, South Yarra	1875
Muntz, T. B., C.E., Wattle-tree-road, Malvern ...	1873
Mills, A. L., University, Melbourne	1903
Munro, J. J., Civil Service Stores, Flinders-street, Melbourne	1903
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Sweet, George, F.G.S., Wilson-street, Brunswick ...	1887
Swinburne, The Hon. G., M.L.A., "Shenton," Kinkora-road, Hawthorn	1905
Tait, Thos., "Orwell," Robe-street, St. Kilda	1905
Walcott, R. H., F.G.S., Technological Museum, Swanston-street	1897
Ware, S., M.A., Education Department, Melbourne ...	1901
Wilkinson, W. Percy, Govt. Analyst, Melbourne ...	1894
Wisewould, F., 408 Collins-street, Melbourne	1902

Country Members.

Beaumont, E. K., c/o Bewick, Moreing & Co., Kalgoorlie, W.A.	1901
Brittlebank, C. C., "Dunbar," Myrniong, Victoria ...	1898
Desmond, J., R.V.S., G.M.V.C., Central Board of Health, Adelaide, S.A.	1901
Fennelly, Richard, A.M.I.C.E., Kilmore, Victoria ...	1895
Gregory, Prof. J. W., D.Sc., F.R.S., University, Glasgow	1900
Hart, T. S., M.A., B.C.E., School of Mines, Ballarat ...	1894
Heden, E. C. B., B.A., B.Sc., B.E., School of Mines, Castlemaine	1904
Hill, W. H. F., "Glenrowan," Dandenong-road, Windsor	1894
Hogg, H. R., M.A., 6 Clanricarde Gardens, Notting Hill Gate, London W.	1890
Ingram, Alex., Hamilton, Victoria	1903
Maplestone, C. M., Eltham, Victoria	1898
Martell, F. J., School of Mines, Ballarat	1897
McDougall, Duncan, Maryborough, Victoria	1897
Mennell, F. P., Rhodesian Museum, Buluwayo, South Africa	1902
Murray, Stuart, C.E., "Morningside," Kyneton	1874

Oddie, James, Dana-street, Ballarat, Victoria 1882
Officer, C. G. W., B.Sc., "Kallara," Bourke, N.S.W. ... 1890
Officer, Sidney, Maryvale, Edenhope 1890

Powell, Walter D. T., Cape Moreton Lighthouse, Brisbane, Queensland 1886

Tipping, Isaac, C. E., Ballarat, Victoria 1892

CORRESPONDING MEMBERS.

Bailey, F. M., F.L.S., Government Botanist, Brisbane, Queensland 1880

Dendy, Professor Arthur, D.Sc., F.L.S., King's College, London 1888

Etheridge, Robert, Junr., Australian Museum, Sydney, N.S.W. 1877

Lucas, A. H. S., M.A., B.Sc., Sydney Grammar School, Sydney, N.S.W. 1895

Stirton, James, M.D., F.L.S., 15 Newton-street, Glasgow 1880

ASSOCIATES.

Anderson, J., 225 Beaconsfield Parade, Middle Park ... 1903

Baker, Thomas, Bond-street, Abbotsford, Victoria ... 1889
Bale, W. M., F.R.M.S., Walpole-street, Hyde Park, Kew, Victoria 1887
Bennetts, W. R., 184 Brunswick-street, Fitzroy, Victoria 1894
Booth, John, M.C.E., 62 Drummond street, Carlton ... 1872
Brown, A. A., 124 Liardet-street, Port Melbourne ... 1902
Bolton, G. J., M.A., 87 Mt. Alexander Road, Flemington 1904

Cresswell, Rev. A. W., M.A., St. John's Parsonage, Camberwell, Victoria 1887

Danks, A. T., 391 Bourke-street west, Melbourne ... 1883

Ferguson, W. H., Maryland Villa, Camberwell Road, Camberwell. 1894
Finney, W. H., 40 Merton-street, Albert Park 1881
Fison, Rev. Lorimer, M.A., D.D., Essendon, Victoria ... 1889
Fulton, S. W., 369 Collins-street, Melbourne 1900

Gabriel, J., Victoria-street, Abbotsford, Victoria ... 1887
Gatliff, J. H., Commercial Bank of Australasia, Lygon-street, Carlton 1898
Goodwin, A. J., 43 St. George's Road, N. Fitzroy ... 1900
Grant, F. E., Union Bank, Sydney 1898
Grant, Kerr, M.Sc., Ormond College, Parkville 1905
Green, W. Heber, D.Sc., University, Melbourne ... 1896
Grayson, H. J., University, Melbourne 1902

Hall, Robt., F.L.S., C.M.Z.S., Elgar Road, Box Hill 1900
Hardy, A. D., F.R.M.S., Lands Department, Melbourne 1903
Henderson, A. A., B.Sc., 68 Avoca-street, S. Yarra ... 1905
Herman, Hyman, B.C.E., F.G.S. 1897
Holmes, W. A., Telegraph Engineer's Office, Railway Department, Melbourne 1879

Ingamells, F. N., Observatory, Melbourne 1889

Jobbins, G. G. 1902
Jutson, J. T., "Oakworth," Smith Street, Northcote ... 1902

Kenyon, A. S., Heidelberg... 1901
Kernot, Frederick A., 57 Russell-street, Melbourne ... 1881

Lambert, Thomas, Bank of New South Wales, Collins-street, Melbourne 1890
Larking, R. J., "Woorigoleen," Clendon-road, Toorak ... 1905
Law, R., F.I.C., F.C.S., Royal Mint, Melbourne ... 1905
Le Souef, D., C.M.Z.S., Royal Park, Melbourne 1894
Lidgey, E. A., 41 Burke Crescent, Geelong 1894
Luly, W. H., Department of Lands, Treasury, Melbourne 1896
Leach, J. A., B.Sc., Continuation School, Melbourne ... 1904
Lowe, Dr. W., 172 Victoria-street, N. Melbourne ... 1905

Maclean, C. W., "Bronte," Strand, Williamstown ... 1879
Mahony, D. J., B.Sc. 1901
Mattingley, A. H. E., 6 Alfred-street, N. Melbourne ... 1903
Mathew, Rev. John, M.A., B.D., Coburg 1890
McEwan, John, 70 Swanston-street 1898
Melville, A. G., Mullen's Library, Collins-street east, Melbourne 1889
Menz, R. 1902
Miller, E. M., B.A., Public Library, Melbourne 1905

Nicholls, E. B., 164a Victoria Street, N. Melbourne ... 1904

Odling, F. J., C.E., Metallurgical Laboratory, Princes Bridge, Melbourne	1905
O'Neill, W. J., Lands Department, Melbourne	1903
Phillips, A. E., Box 396, G.P.O., Melbourne	1883
Pritchard, G. B., F.G.S., Mantell-street, Moonee Ponds	1892
Sayce, O. A., Harcourt-street, Hawthorn	1898
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Wedeles, James, 231 Flinders Lane, Melbourne	1896
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Woodward, J. H., Queen's Buildings, Rathdowne-street, Carlton	1903